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FOSTERING INFRASTRUCTURE DEVELOPMENT ALIGNED WITH SUSTAINABLE DEVELOPMENT GOALS

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Infrastructure development plays a crucial role in accelerating the sustainable economic growth and development of a country. The increased provision of public infrastructure can help raise the GDP growth level by lowering production costs, enlarging markets, raising total factor productivity, and facilitating economic activities. Furthermore, infrastructure helps improve the living standards of the people by providing jobs and building the local suppliers' and developers' capabilities, which contribute to reducing poverty and improving development outcomes.

On the other hand, infrastructure is also crucial and lies at the core of efforts to achieve sustainable development. It encompasses many aspects of the Sustainable Development Goals (SDGs), such as health, education, access to energy, as well as clean water and sanitation. The infrastructure improvement is implied in most of the targets of SDGs. The importance of infrastructure must take the sustainable development dimension into account; hence greater efficiencies can be obtained to achieve SDGs successfully.

Despite its potential benefits, infrastructure development that is poorly planned, implemented, or operated brings negative consequences for the society, which is escalated by an overrun budget and ineffective usage. Therefore, an infrastructure system must be developed to meet sustainability needs. Sustainability in infrastructure can be comprehended as how the attributes of the practices, products, services, and resources used in the infrastructure development can contribute to the continuation of ecosystem components and functions for generations in the future. Infrastructure projects must deliver better value by going hand-in-hand with sustainability, projecting its benefits and costs towards both the short-term goals and long-term implications.

In order to be aligned with the dimension of sustainability, infrastructure needs to consider the economic, social, and environmental aspects. In terms of the economic aspect, infrastructure development should contribute to overall growth by supporting inclusivity, boosting productivity, and delivering accessible and affordable services. In terms of the social aspect, infrastructure is supposed to improve livelihoods, enhance human well-being, and remove poverty in all forms. Lastly, in terms of environmental aspects, the development of infrastructure should preserve the natural environment, ecosystems, and the biodiversity within by supporting the use of high-energy efficiency standards and promoting the resource-efficient approach contributing to reducing overall carbon emissions during its lifecycle.

As sustainable infrastructure becomes a cornerstone to achieving the SDGs; therefore, the long-term vision for developing a national infrastructure system informed by SDGs should be ensured. We argue that these visions can be delivered by establishing adaptable plans that include implementing low-carbon solutions and resource-efficient, ecologically based, and energy-efficient technologies.

Sustainable Technologies-related Research

Technology provides alternative solutions to achieve sustainable development goals. In this edition of the CSID Journal of Infrastructure Development, nine papers dedicated to studies related to sustainable technology are presented.

The first paper, written by B. Susantono and S.H. Li, discussed the experience of Singapore in combating water challenges. Their findings showed that urban water in Singapore has undergone extensive holistic planning, supply and demand management, as well as constant efforts in technology advancement and innovation. Despite current progress Singapore has been developing, the author proposes solutions to tackle water issues in Asian and Pacific countries including diversifying water sources and reducing NRW, increasing energy efficiency and exploring renewable energy, as well as engaging private sector investment.

The second paper, written by R. Shankar and W. Tan, elaborates on the understanding of spatial distribution of monetized road assets using Toll-Operate-Transfer (TOT) model. The author found that the scheme had different results on two project auctions in terms of asset quality, political factor, strategic factor, social factor and project outcome. Their findings highlight the importance of political considerations and experimentation in selecting auction assets. The result also showed that government-controlled auctions produce more favourable outcomes for related parties.

The third paper, written by N.V. Tam, review publications related to public private partnership (PPP) in the infrastructure sector during the last two decades. The author used bibliometric analysis in order to generate targeted results. The author found the PPP publication dramatically increased from 2008 onwards. The author explored four main themes of research on PPP for infrastructure including research on success factors of PPP for infrastructure projects, research on risks of PPP for infrastructure projects, research on financing of PPP for infrastructure projects and research on relationship among parties of PPP for infrastructure projects. Future research direction suggested to focus on social and environmental impact assessment for PPP models development, and performance evaluation criteria for PPP projects long-term viability.

The fourth paper, written by C. Hadu, and E. Ellisa, examined the significance of informality which shapes a compact urban form in the 'desakota' area. 'desakota' is a peri-urban area that suffers environmental degradation in the economy and socio-culture due to poor planning and control from state and local authority. The author used Tangerang - a neighboring area of the capital city of Indonesia as the case study. The findings showed that there is a dialectical relationship between informality and the physical environment that is still a largely neglected issue in peri-urban studies. The article concluded that the informality potents should be considered for designing 'desakota' to maintain its compact form and create a more sustainable urban form and a better urban life.

The fifth paper, written by W. Nwaki, E. Eze and I. Awodele, elaborates major barriers to lean construction application on construction project delivery. The author took Nigeria as the case study, and found some barriers of lean construction that should be dealt with related stakeholders in construction projects. It includes technology and knowledge barrier, leadership and management barrier, culture and complexity barrier, engagement and relationship barriers, financial barriers, and communication barriers. Author further stressed the need to incorporate leadership and management support to improve lean construction knowledge and practice.

The sixth paper, written by D.R. Fatma and Y. Lukito, discusses how Petang Megang reflects the connection of local people to the river and influences the spatial form of the Siak riverside. Petang Megang is known as a tradition to clean and purify the body and soul to welcome the holy month of Ramadan. Currently, the local government has paid more attention to the ceremony by involving more competitions and festivals to attract tourists, but this action limits access of local people to the

river. Therefore, a balanced solution between accessibility and profitability should be further elaborated.

The seventh paper, written by J. Maina, M. Dagoli, A. Abdulkadir, N. Muhammad, I. Muhammed, B. Yusuf, T. Mtan, and M. Abdulrazaq, investigates satisfaction of dwelling unit attributes, support services and infrastructure within public housing estates across Northern Nigeria. The author argued that residents perceive satisfaction with dwelling unit attributes and infrastructure in terms of design and cost, services and IEQ as well as electricity supply and noise levels. The paper recommends some improvement of public housing related to building quality, indoor environmental quality, and technology adoption.

The eighth paper, written by I. Anum and O.F. Job, ameliorating the negative impact of plastic inclusion for concrete strength behavior through pulverisation and chemical treatment of High-Density Polyethylene (HDPE). The result illustrated HDPE content beyond 0.5%, restrained hydration takes negative effects on the concrete. It was also shown that the designed compressive strengths of the tested samples were satisfactorily met in all cases indicating improvement in the compressive behaviour of the samples. The author suggested that pulverised HDPE could be used as an admixture in concrete without compromising their compressive strengths.

The ninth paper, written by S. Agarwal, T.P. Nanda, R. Bali and A. Soni, check the feasibility of an Urban Land Data Repository, drawn from the Real Estate Regulation Act 2016, by taking into account Indian four states of Uttar Pradesh, Madhya Pradesh, Haryana, and Maharashtra. The paper details the data points and the rationale for taking them, closing with an analysis of the current data availability for the proposed repository through this policy analysis paper.

We hope that this edition may convey new insight and knowledge that bring benefits to our readers. We welcome any comments or inquiries that you may have concerning the direction and the content of this journal. We also invite you to join our venture by sending your work for future consideration.

Warmest regards from Editorial Office,

Dr. Mohammed Ali Berawi   Mustika Sari   Perdana Miraj
Editor-in-chief   Managing Editor   Managing Editor

URBAN WATER FUTURE: WHAT CAN WE LEARN FROM THE SINGAPORE EXPERIENCE?

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ABSTRACT

Asia and the Pacific region is a hot spot for water insecurity in the world. With water resources such as ground and surface water depleting, the demand for water consumption increases as urban population continues to grow. Meanwhile, non-revenue water (NRW) leads to inefficient water service delivery, waste of energy, drinking water contamination, loss of revenue, and increased operation costs. As the water stress continues in the region, what can cities in the region do to sustain their water future? To answer this question, this paper uses Singapore as an example and draws lessons from its urban water management experience. It finds that countries can take away from Singapore knowledge and practices, including institution autonomy paired with people-centric management, inter-agency coordination, emphasis on demand management, non-revenue water (NRW) regulation, as well as technologies and innovations. Apart from these, this paper also finds that the remaining water challenges faced by Singapore, such as climate change, energy dependence, and financial sustainability, are also shared by cities in developing Asia and Pacific countries. This paper therefore proposes solutions such as diversifying water sources and reducing NRW, increasing energy efficiency and exploring renewable energy, as well as engaging private sector investment as some of the first steps in tackling those shared challenges.

Keywords: Water insecurity; non-revenue water; Singapore; urban water future; people-centric management; urban water management; private sector investment

1. INTRODUCTION

Water is at the core of sustainable urban development. Without water, cities will not be able to sustain economic growth. Continuous urbanization, growing population, and intensified economic production have drastically increased the demand for water, while environmental degradation, natural disasters, and climate change are putting pressure on the supply of the already diminishing resource. It is estimated that the global economy loses $500 billion USD per year due to water stress issues (OECD, 2012). Meanwhile, water is also a cross-sectoral issue that's linked to several global challenges such as public health. The recent coronavirus disease (COVID-19) pandemic has demonstrated the importance of water, sanitation, and hygiene services. For billions in the world to be able to wash hands with clean water and soap, governments must provide quality access to clean water for all population, especially the most vulnerable, in order to fight the virus. Water security is therefore an urban planning and policy issue that remains pivotal for cities thriving to become inclusive, sustainable, and livable.

Asia and the Pacific region is a hot spot for water insecurity in the world, with around 600 million people still lacking access to basic water service (Asian Development Bank, 2016; UNICEF & World Health Organization, 2019). To improve water security for cities in this region, it is crucial for policymakers to draw lessons from advanced economies. Singapore for instance has observed notable success from the management of their water. In 2007, Singapore won the prestigious Stockholm Industry Water Award for its "holistic approach to water resources management which made water use sustainable for different sectors of society in a unique and challenging urban island environment." While we can acknowledge the city-state's unique social, economic, and political nature, there are transferable lessons and takeaways from Singapore's urban water management story that can help to build a methodology available for others. Based on a rich reservoir of existing research, this paper contributes to this topic through discussing Singapore's latest water management updates and innovations, urban water management from similar utilities, as well as lessons and common future concerns that can serve as benchmarks in designing and managing future urban water utilities for developing Asian cities.

This paper proposes to examine Singapore's water journey in a systematic way, and identify key policy lessons for developing Asia and Pacific countries to achieve a sustainable water future. Based on site visits conducted by the Asian Development Bank in Oct 2019 in Singapore, as well as its years of practical experience assisting the region in water management, this paper aims to answer two questions: 1) how Singapore's urban water management has been effective, and 2) how cities in developing Asia and the Pacific countries can translate Singapore's experience for their own urban water development.

2. URBAN WATER MANAGEMENT ISSUES IN ASIA AND THE PACIFIC REGION

Rapid urbanization has brought significant economic growth to Asia and the Pacific region in the past decades. However, water security is still a concern. While a lot has been achieved over the years, 29 out of 48 economies in the region are still categorized as "water insecure" by 2016 (Asian Development Bank, 2016).
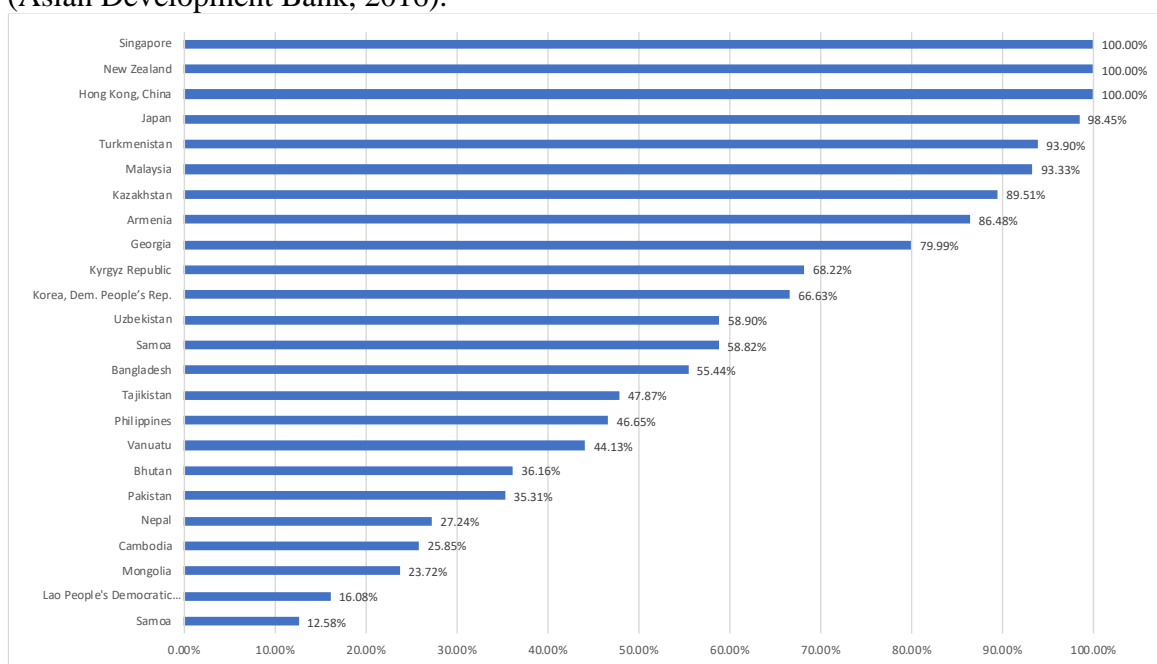

Figure 1 Percentage of population using safely managed drinking water services in Asia and Pacific countries (with available data) in 2017 (World Bank, n.d.).

The coverage and reliability of water supply and service is the first concern. There is a population of 1.7 billion people in the region lacking access to basic sanitation (Asian Development Bank, 2016). Urban slum dwellers are among those who commonly lack access to clean water supply and sanitation, making slums the weak link of inclusive and sustainable urban development, especially during infectious disease outbreaks. The COVID-19 pandemic has further exhibited the importance of quality and inclusive urban infrastructure, including water, sanitation, and hygiene services, among others. Water resources are also depleting as the region has already accessed available surface and groundwater. Seven of the world's 15 biggest groundwater abstracting countries are in this region, especially in East and South Asia (Asian Development Bank, 2016). Even in urban areas in Asia where there's water supply, people do not always benefit from reliable supply available on a 24*7 basis.
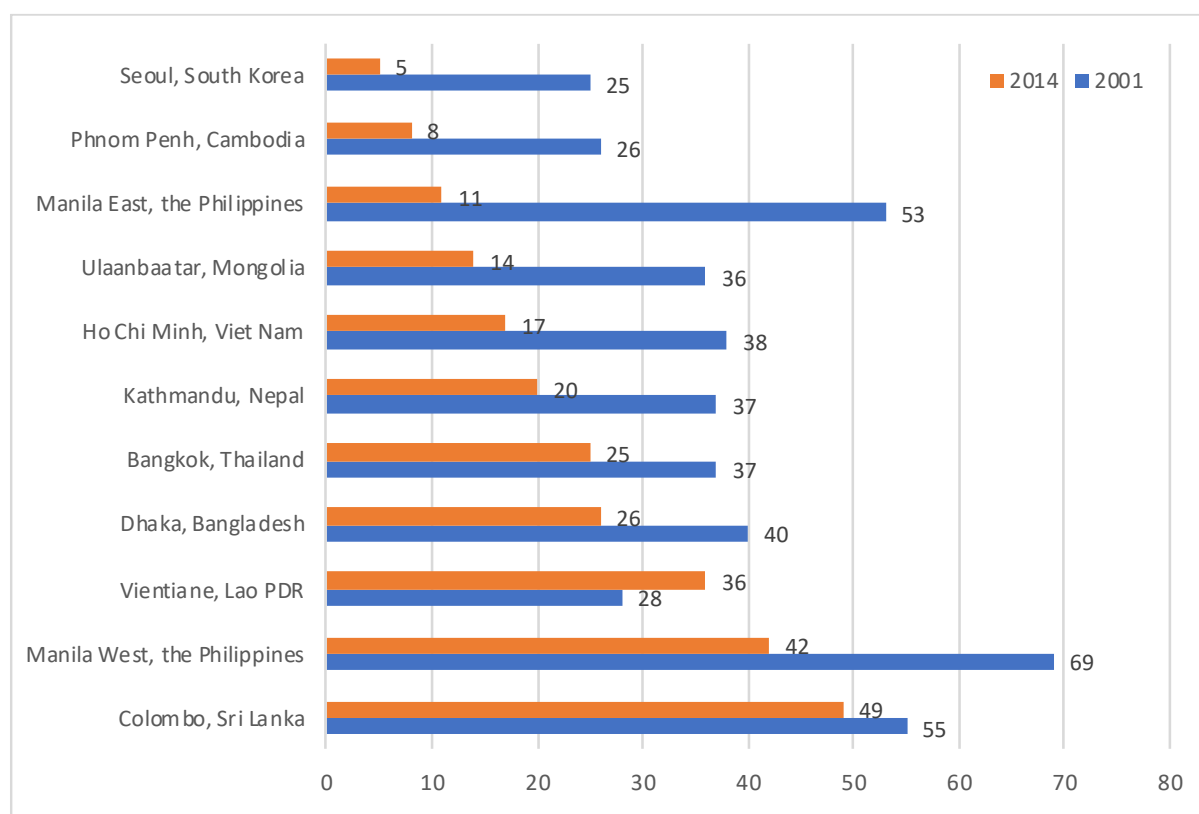

Figure 2 Percentage of Non-Revenue Water Levels in Selected Asian Cities (2001 and 2014)
(Asian Development Bank, 2016)

Non-revenue water (NRW) is also a major problem in developing Asia and the Pacific countries and a cause of non-accessibility of water for end users. NRW measures the water lost in physical losses as leaks, and commercial losses as illegal connections. NRW in many cities is still above 50% (Asian Development Bank, 2016). Even within countries, NRW can also vary. For example, in Malaysia, NRW varies from 18% to 73% among different states (Araral & Wang, 2013). Reasons for high NRW include water leakage from aging infrastructure, inefficient operations and maintenance practices, poor metering system, and water theft. NRW can lead to inefficient water service delivery, waste of energy, drinking water contamination, loss of revenue, and increased operation costs (Araral & Wang, 2013; Asian Development Bank, 2016).

Meanwhile, the region's water demand is surging. Asia and the Pacific region is predicted to be home to 5.2 billion of the world's total population by 2050, with an estimated 3.4 billion people living in water-stressed areas (Wiberg et al., 2017). As rapid urbanization and economic transformation continue, the region will host 22 megacities by 2030, burdening the already limited water resources (Asian Development Bank, 2016). Compounding these challenges, the region also faces increasing water-related natural disasters and climate impacts, adding pressure to existing water security issues. The region's water demand is projected to increase by about more than half, due to the growing needs for both domestic and non-domestic water usage, including manufacturing, agriculture, and thermal electricity generation (Asian Development Bank, 2016; OECD, 2012). Therefore, the need to secure the region's water future is urgent.

3.   HYPOTHESIS AND ANALYTICAL FRAMEWORK

From the brief discussion of issues on urban water management in Asia and the Pacific, this paper proposes a simple hypothesis: the common goal of a water utility is to provide 100% water service coverage, and that despite some cities achieving 100% coverage, there are no common success elements, previous and remaining challenges, as well as governance mechanisms that apply to all.
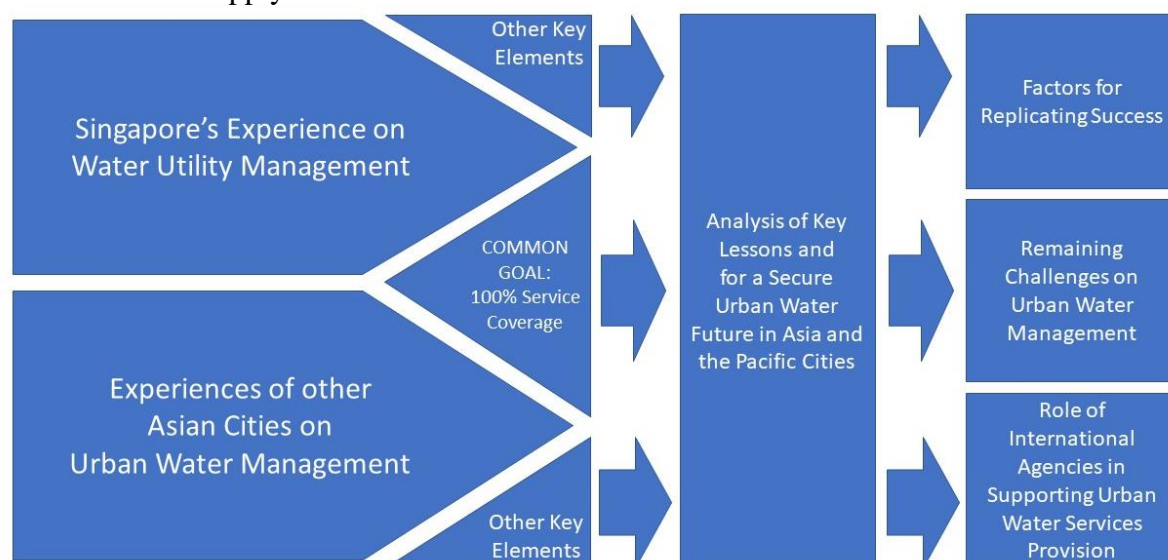

Figure 3 Analytical Framework (Asian Development Bank, n.d.)

Under this hypothesis, this paper implies an analytical framework taking the form of a jigsaw puzzle (Figure 3) to look into different key elements of Singapore and other successful water utilities in Asian cities with a common attained goal of having 100% water supply service coverage. Discussion about lessons learned from Singapore and other cities are then grouped into three main areas: factors for replicating success; remaining challenges, and the role of international agencies in supporting urban water service provision. The data in this paper came from literature review on historical and operational information on Singapore's water utility development, as well as observation and conversational data gathered from authors' visit to Singapore's water supply facilities.

4.   SINGAPORE'S URBAN WATER MANAGEMENT EXPERIENCE

Today in Singapore, one can simply put a glass under a running tap and get clean drinking water. But just some 50 years ago, people still queued on streets for water during dry seasons. Having only three reservoirs meeting 20 percent of its demand at that time, Singapore relied the

rest of its water supply on transfers from Malaysia. The two water agreements Singapore signed with Malaysia, one already expired, and the second one, which allows Singapore to withdraw 250 million gallons of water (1.14 million cubic meters) per day from Johor River, will expire in 2061 (Tortajada et al., 2013). While the independence accord guarantees the execution of the water agreement, Malaysia threatened to turn off the water supply if Singapore did not support its foreign policy (Luan, 2010). Singapore's water supply issue became a matter of national security.

Therefore, it was crucial for Singapore to gain water independence for its own survival. Since its independence, Singapore has adopted a holistic approach to transforming its water vulnerability into one of the world's best examples of water management.

4.1. Supply Management

Singapore embarked its water dependence path through diversifying its water sources. The current "four national taps", including water imported from Malaysia (up to 60%), local catchment (10%), desalination (up to 30%),[1] and NEWater or reclaimed water (up to 40%), supply the country's water needs from both households and non-domestic sectors. The goal is for desalination and NEWater together to be able to supply 85% of Singapore's water demand by 2060 (Public Utility Board, 2016).
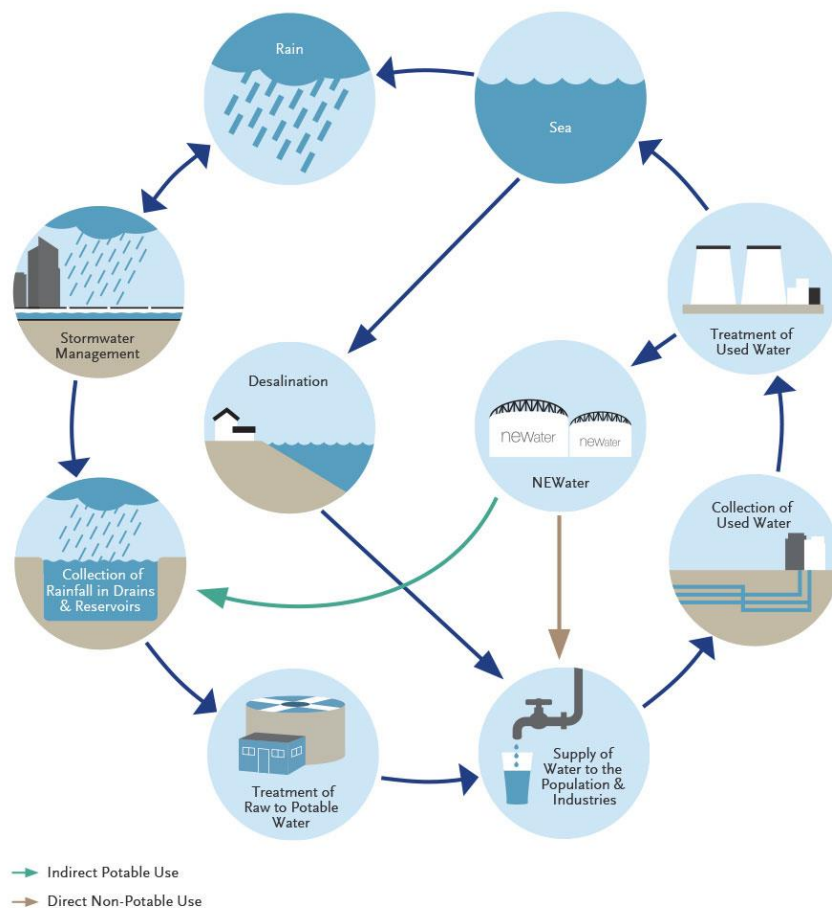

Figure 4 Singapore's water loop (National Council of Social Service, n.d.)

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[1] "Up to 30%" refers to Singapore is able to supply 30% of its water needs through desalination when operated in full (same for NEWater). Currently the country still relies more than 50% of its water supply on Malaysia.

The Public Utility Board (2016), Singapore's national water authority, has summarized three key water policies for this successful diversification. First, ensuring every drop of water falling into Singapore is collected. Singapore has so far expanded its local water catchments into 17 reservoirs and a network of rivers, canals, and drains, together covering two-thirds of the island to ensure rainfall storage (Public Utility Board, n.d.-a). Second, positioning water as a reusable product that can be reclaimed. The catchment expansion process also separated Singapore's sewage and drainage system, which laid the groundwork for more efficient used water collection and treatment. And third, utilizing Singapore's surrounding natural resource - seawater for desalination. Supported by these strategies, PUB has closed its water loop to make full use of its water resources.

4.2. Demand Management

Apart from managing water supply, Singapore has also been taking efforts in managing its water demand. Singapore currently needs about 430 million gallons of water a day (about 1.6 million cubic meters per day), with 45% and 55% coming from domestic (households) and non-domestic (businesses) sectors respectively. The total demand in 2060 is estimated to double, with non-domestic sectors taking up 70% of the consumption. Singapore plans to supply this increased water demand mainly through NEWater and desalination (up to 85%).

Singapore's water demand management policy instruments include pricing and non-pricing mechanisms such as public education (Qi et al., 2016). Water tariff in Singapore includes the cost of water production and supply, water conservation tax and waterborne fee, with Goods and Service Tax (GST) on top of the total price. For households, water tariff can vary between $2.01 (monthly water usage less than 40m3) to $2.71 (after usage exceeds 40m3) USD/m3 (PUB 2019e). This price is ranked the highest in Asia (Araral & Wang, 2013; Danilenko et al., 2014)[2]. Meanwhile, PUB also encourages water conservation through water-saving campaigns, water efficiency awards, mandatory water efficiency labeling on household appliances (Public Utility Board, 2016). Through these measures, Singapore has reduced its water consumption from 165 liters per capita per day to 141 liters in 2018, and targeting 140 liters in 2030 (Public Utility Board, n.d.-c, 2016).

Another important aspect of demand management is Singapore's strategy in reducing non-revenue water (NRW)[3], including commercial and physical losses in the water network. Singapore's entire water system is metered, from water supply to the consumer side (Tortajada & Buurman, 2017). This means there are very few illegal connections and all water activities are monitored, minimizing water commercial losses. At the same time, more than 300 sensors installed islandwide monitor potable water pressure and detect early pipe burst (Public Utility Board, 2019). This helps reduce physical water losses due to pipe leaks. In 2018, Singapore's NRW is 5.6% out of total water production, one of the lowest in the world (Public Utility Board, n.d.-c).

4.3. Technology and Innovation

Singapore's trajectory to water independence is also a constant path of pursuing better technology and innovation. Since 2002, Singapore together with many collaborators have

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[2] According to PUB, despite the high price, the average household's water bill however remains a small portion of its income, considering factors such as subsidies and the country's income level.
[3] In Singapore, NRW is referred to as Unaccounted-for Water (UFW).

invested $724 million SGD ($532 million USD) in water R&D (Public Utility Board, n.d.-c). Some of the technologies and innovations are mentioned here.[4]

Reducing the cost of desalination through R&D. Desalination is by far Singapore's most energy-intensive and therefore most expensive method to produce water (see Annex for details). Singapore's desalination adopts reverse osmosis (RO) technology for seawater treatment. Through the RO process, seawater is pushed through membranes to remove dissolved solids such as salts and minerals and produce pure drinking water. The RO technology currently requires about 3.5kWh/m^3. This means to process 100 cubic meters of seawater through RO technology, the electricity required is enough to power a 40W fridge for about a year.

Validating technologies to improve energy efficiency in the water sector. Singapore has set up the Integrated Validation Plant (IVP) to test and validate new and innovative technologies such as advanced used water treatment before full deployment in the future. For example, the IVP demonstration process allows to not just treat used water, but also produce biogas and increase energy self-sufficiency. The process has also achieved the lowest energy consumption at 0.3 kWh/m^3, compared to 0.5 kWh/m^3 for conventional treatment.

Enhance efficiency and sustainability through smart technologies. PUB has set up a SMART PUB Roadmap to identify and integrate technologies for its water future. At the Integrated Validation Plant mentioned previously, data generated by smart cameras and environmental sensors are integrated into a platform, and artificial intelligence is adopted to alert potential abnormalities of the water system. This contributes to a less manual dependent water operation and reduced human error (Public Utility Board, 2019). It also helps to reduce the plant's energy costs by 5%, according to PUB.[5]

Another important technology refers to Singapore's smart metering system. Currently, the country's 1.6 million water meters are read once every two months manually.[6] With the Advanced Metering Infrastructure (AMI) enabled smart meter, water consumption can be read automatically several times a day, with data being transmitted daily back to PUB (Ai-Lien, 2019; Public Utility Board, n.d.-c). This will improve PUB's resource efficiency through minimizing manual meter readings, and contribute to the reduction of NRW. Customers will also be able to monitor their water consumption through a mobile application, with notifications of water leaks and high usage, which encourages water conservation behavior.

5. URBAN WATER MANAGEMENT HIGHLIGHTS FROM OTHER CITIES IN THE REGION

Today in Singapore, one can simply put a glass under a running tap and get clean drinking water. But just some 50 years ago, people still queued on streets for water during dry seasons. Having only three reservoirs meeting 20 percent of its demand at that time, Singapore relied the rest of its water supply on transfers

5.1. Dhaka: Supplying Water for All

The City of Dhaka went through a water service turnaround, with a special focus on supplying water for urban slums. The Dhaka Water Supply and Sewerage Authority (DWASA) was initially reluctant over supplying water to the poor, citing reasons such as the lack of necessity of individual connections and the inability of the poor to afford these services (Sharma &

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[4] Information in this section was gathered through field trips and conversations with PUB senior officials.
[5] Information gathered during ADB's site visits to PUB on 23 October 2019.
[6] Water bill is estimated during months when the bill is not read. If a customer is overcharged due to inaccurate estimation, he or she can submit meter readings for a refund.

Alipalo, 2017). This mindset not only marginalized the vulnerable urban community, but also further threatened water pressure and public health condition in the city. As Dhaka is reliant on groundwater to constitute towards 80% of its water supply, the city is already facing an alarming groundwater depletion rate at 2-3 meters per year (Islam et al., 2018). Without proper water supply, there is a high likelihood that the impoverished would continue illegal pumping, resulting in the worsening of existing water pressure issues across the city (Sharma & Alipalo, 2017). Meanwhile, without access to clean water and sound sanitation, urban slums are also exposed to infectious disease outbreaks, stressing public health conditions. Under a long from the Asian Development Bank (ADB), DWASA initiated projects to provide connections of safe drinking water supplies to slums. Moreover, based on ADB's project assessment, the high payment rate among two pilot slums was indicative that the poor value and were willing to pay for quality water access (Sharma & Alipalo, 2017). For Dhaka, this shift in mindset towards its water management was a breakthrough that paved the way towards providing water for all.

Meanwhile, to sustain its water future, Dhaka is on also its trajectory of reducing dependency on groundwater and diversifying its water sources. DWASA plans to increase surface water supply, with measures such as increasing institutional capacity to attract investment and reducing surface water pollution (Islam et al., 2018; Sharma & Alipalo, 2017).

5.2. Phnom Penh: Reducing NRW is Key

Phnom Penh managed to transform from a broken post-war water system to a modern around-the-clock citywide water supply. One notable success is the city's effort in NRW reduction. According to Phnom Penh Water Supply Authority (Phnom Penh Water Supply Authority., n.d.), several measures were implemented to reduce water loss, namely: a) updating and correcting its customer database to improve water bill collection rate; b) installing efficient and quality meters on all household connections, accompanied with a regular meter examination and replacement program, to measure water consumption accurately; c) upgrading and replacement of old pipes to prevent water leaks; d) establishing water leakage repair groups to ensure timely and quality repairment of water pipes; and e) provide training, as well as a punishment and rewarding system, to improve staff quality and prevent misconduct. These measures were seen as contributing factors that resulted in the reduction of NRW from 72% in 1993 to 8.2% in 2018 (Phnom Penh Water Supply Authority., n.d.).

At the same time, PPWSA has also worked on increasing tariff to cover operation, maintenance, and asset depreciation costs. It's worth mentioning that PPWSA went through a few lessons before settling on its current policy to target the poor. The initial policy, which selling subsidized water to community representatives who in turn resold the water to the poor, failed due to corruption among community representatives and the collection amount was also too low (Biswas & Tortajada, 2010). Instead of supply free water to the poor, the policy was transformed a targeted subsidy program, with extra efforts to inform and educate the poor, that allows households to repay the bill over a period of 10 to 20 months and receive 30% to 100% subsidy based on their financial ability (Biswas et al., 2021; Spencer & Meng, 2019). Together with previous NRW efforts, PPWSA managed to recover costs and provide water across all income groups in Phnom Penh.

5.3. Seoul: Infusing Technologies for Efficiency

Having achieved 100% tap water supply coverage in 1991, Seoul has been utilizing digital technologies to improve water system efficiency and deal with new challenges. Similar to Singapore, the highly urbanized Seoul Metropolitan Area faces the issue of higher frequency of

urban flooding as a result of change of climate (Choi, 2015). Pollution caused by urban flooding can damage Seoul's only water supply – Han River and further lead to issues like drinking water contamination. From the technology aspect, Seoul has deployed a supply control system that monitors water quality and pressure, a production control system that forecasts demand using weather and consumption data, a remote control system that collects and analyzes operation and purification points with CCTV, a Seoul Water New System that enables real-time water quality testing and control – all these are integrated into one GIS-based operation system named Arisu Combined Information System, helping the city provide timely response and decision-making over its water system, including its urban flooding challenges (The Office Of Waterworks Seoul Metropolitan Government, n.d.).

6.   LEARNING FROM SINGAPORE AND OTHER CITIES' URBAN WATER EXPERIENCE

As mentioned previously, this paper will look into different key elements of Singapore and other successful water utilities in Asian cities. These key elements will be grouped into three main areas for discussion: factors for replicating success; remaining challenges, and role of international agencies in supporting urban water service provision.

6.1. Transferring Success

Having achieved 100% tap water supply coverage in 1991, Seoul has been utilizing digital technologies to improve water system efficiency and deal with new challenges. Similar to Singapore, the highly urbanized Seoul Metropolitan Area faces the issue of higher frequency of urban flooding as a result.

Institutional autonomy and people-centric management enable efficient water management. Being the only authority in charge of all water affairs, the corporatized PUB has a high level of autonomy in designing and implementing water policies and initiatives without relying heavily on interdepartmental coordination. Similar water specialized agencies include previously mentioned PPWSA from Phnom Penh, DWASA from Dhaka, among others. This has contributed to both institutional efficiency and financial sustainability for PUB. Singapore's PUB was able to increase water tariff progressively and tap into the commercial market issuing bonds, generating cash for its own operations and other investments (Tortajada, 2006). Such autonomy also allows PUB to have a great say in its human resource management. Staff remuneration is benchmarked against Singapore's civil service, which is in turn benchmarked against the market. Such a competitive benefits package creates strong incentives for employee performance. Meanwhile, staff are also provided with training opportunities, which contributes to staff self-development and therefore organizational competency as a whole (Public Utility Board, n.d.-c; Tortajada, 2006).

Water management also takes inter-agency efforts. While PUB has full ownership of the entire water system in Singapore, integrating water into long-term sustainable planning requires institutional coordination across government agencies. In the 1970s, Singapore initiated the movement to clean up the Singapore River, and coordinated among environment, housing, industry, land planning and other agencies. The river clean-up wouldn't be successful without inter-agency implementation. PUB's current water treatment technology testing, such as the co-digestion mentioned earlier, also relies on the National Environmental Agency to provide testing materials such as waste food. As water is the essential element cutting across all industries and sectors, inter-agency coordination provides enabling environment and institutional support for integrated water management.

Managing demand is as important as managing water supply. With increasing water demand due to population growth as well as diminishing supplies result from changing climate,

cities have come to realize the importance of water consumption management. Just recently, the historical sharp fall of Mekong River levels due to dry season has made aware the government of Cambodia and its residents of the urgent need for water conservation. The COVID-19 pandemic has further called for water resource conservation as one of the pathways to a low-carbon and resilient future (Asian Development Bank, 2020b). For Singapore, its "valuing water" demand management is viewed as crucial to its success (Tortajada, 2006). Pricing is an important tool in regulating water demand in Singapore. Data shows that block water tariff increase has become an effective instrument in influencing consumer behavior and has contributed to an overall decrease in water consumption in Singapore. To emphasizing water as a scarce and precious resource, a progressive tariff reform in 1997 increased the water price by 120% (rolled out over a four-year period), created strong incentives for water conservation. In 2017, Singapore announced another round of tariff increase (30%) due to the increasing cost of water supply (Min, 2017). In addition, 30% of the total water tariff consists of the water conservation tax,[7] which further stresses the importance of water saving. Compared to before the 1990s, when the tariff was designed to only recover the cost of water supply, today's water tariff in Singapore reflects the higher prices of alternative supply methods such as desalination. For developing Asian countries, the effectiveness of Singapore's tariff transformation suggests that water, while being an essential daily good, can be charged based on economic efficiency and be used to regulate consumer behavior with social considerations as explained hereafter.

Water pricing needs to consider equity. Inequality exists in water bills. In developing countries, the poor often have to purchase bad quality water at a higher price from water vendors due to unstable water supply and services in their areas. Apart from solutions such as ensuring coverage, the water tariff structuring should balance affordability and sustainability to account for equity. While Singapore has the highest water price in Asia, it also provides rebates (called U-Save Program) for households who cannot afford to pay the current tariff. During COVID-19 pandemic, Singapore government also provided rebates through U-Save to residents living in public housing, to support utility payments during disruptive times (Government of Singapore, 2020). Multiple research also confirms that instead of providing subsidized water for all and potentially benefiting the wealthiest more, targeted subsidies for the poor are more efficient in achieving equity (Connor, 2015; Tortajada, 2006; Wichelns, 2013). The previously discussed practices from Dhaka and Phnom Penh provide further evidence supporting this view.

Regulating NRW is important for sustainable water management. In reducing NRW, Singapore has over the years ensured a 100% coverage of its metering system, as well as gradually replaced old and leaking pipes (Araral & Wang, 2013). The country also addresses NRW challenges through asset management. From forming a good understanding of the age of the pipes, to conduct annual checks for all pipes, to deploy sensors to monitor water pressure, and to implement risk-based asset management software to schedule pipe replacements, PUB is building its ability to anticipate and react to network failure while minimizing interruptions to water operations. Meanwhile, digital technology is also utilized to increase metering accuracy in order to further reduce NRW. These technical solutions are coupled with regulatory tools including legislation for non-compliance, as well as the demand management zones approach, to better regulate and monitor water consumption and NRW (Araral & Wang, 2013; Tortajada & Buurman, 2017). These measures are not new nor unique to Singapore, but they require effective governance to turn ideas into implementation. The successful transformation of Phnom Penh's water supply has proven that developing Asian cities can also achieve

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[7] For domestic consumption, if the monthly consumption is over 40 cubic meters, the water conservation tax is increased to 45% of the total price.

remarkable NRW reduction results with good governance. Developing countries in the region can draw from these lessons for their own NRW management.

Innovation is more than technological innovation. To start with, it is important to build data infrastructure and data management capacity as part of the enabling environment for more and better use of innovative solutions. In Singapore and Seoul's cases, the two water utilities were able to transform into smart water management through digitizing water infrastructure, harness quality data, creating digital database, and translating numbers into information that informs more efficient and effective evidence-based decision-making, and leveraging more cutting-edge solutions such as GIS mapping, artificial intelligence, and digital twin (Jun, 2014; Public Utility Board, 2020). In comparison, most developing Asian and Pacific cities still lack water-related data and information, resulting in limited water and sanitation services, water resources management, and water-related disaster information systems (Asian Development Bank, n.d.). Enhancing water-related data production and management can be the first step towards improving urban water management for developing Asian cities.

Other than innovative technology, institutional adaptability can facilitate technological development for water management. One good example is PUB's revisit to the possibility of using desalination after technology evolved, instead of insisting on its initial assessment years ago (Qi et al., 2016). Instead of maintaining the status quo, it is useful for governments to be adaptive, revisit, and update water planning as technology improves. Meanwhile, innovation can also be about facilitating private sector engagement. Apart from technology and R&D, Singapore has also been innovating in creating the ecosystem for engaging the private sector. The example here is the Singapore Water Exchange (SgWX). Launched in 2018, SgWX is a designed space for water companies along the water value chain to operate and collaborate, and therefore push water innovation and industry growth (Public Utility Board, n.d.-b). Similarly, Seoul has also established Waterworks Research Institute, focusing on developing new technology that contributes to Seoul's sustainable water supply (The Office Of Waterworks Seoul Metropolitan Government, n.d.). Innovations like these add to the enabling environment for better water management in urban areas.

6.2. Remaining water security challenges shared by Singapore and other countries

Changing weather patterns affect water supply and service reliability. The Centre for Climate Research Singapore has projected that Singapore will experience hotter temperatures, as well as more extreme dry season and rainfalls (Public Utility Board, 2016). Compared to its 1981-2010 long-term average, Singapore's rainfall recorded in 2018 was about 21% lower (Meteorological Service Singapore, 2018). The same issue could also affect the Johor River next door, which Singapore draws daily water from. In tackling this, Singapore's strategy is to diversify 85% of its water supply coming from desalination and NEWater by 2060, and therefore reducing its dependence on rainwater. While most developing countries in this region, unlike Singapore, are blessed with natural water resources, it doesn't mean water scarcity would not become an issue in the near future. Singapore's unique situation can inspire cities to conduct future thinking and prepare for potential water security issues through measures like securing additional water resources (such as water reclamation) to reduce water shortage risks, and in parallel to reduce NRW to acceptable levels and to manage water demand.

Another challenge brought by urbanization and changing climate is urban flooding. For cities where water supply relies heavily on surface water, changing rain patterns could increase the frequency of floods and droughts, therefore impact water resources in the region (Asian Development Bank, 2016). Both Dhaka and Phnom Penh's flood risk management are supported by city-level masterplans for sewerage and drainage systems. Singapore is also

working on widening and deepening its waterways to reduce flash flood risks, and considering rising ground levels and installing flood barriers to protect itself from rising sea levels and storm surges (Public Utility Board, 2016). Seoul, on the other hand, has taken a step further and gone beyond government-led flood control measures. Apart from traditional flood control measures that typically consist of above-mentioned structural measures (such as sewage system expansion, rainwater pumping) and non-structural measures (such as flood maps, evacuation plans), Seoul's comprehensive approach also brings in private sector insurance to ease the financial burden of previously government-funded disaster compensation (Choi, 2015). The previously mentioned water quality control technology and Combined Information System adopted by Seoul can also contribute to monitoring water quality during flood season to prevent and respond to water contamination.

The growing energy demand as water demand increases. With Asia and Pacific's rapid urbanization and urban population growth, the region's water demand is projected to increase by 30-40%, with much of the region's existing groundwater resources already being fully utilized (Asian Development Bank, 2016). Meeting such demand under the impact of climate change requires solutions such as desalination and water reclamation, which requires a substantial amount of energy. For countries like Singapore, balancing water independence and energy dependence is a challenge. Research argues that while there's a trade-off, compared to water sources, energy dependence is more flexible as it can be purchased from the international market. Besides Singapore, other countries in the region such as India and Australia have also pioneered in energy reduction and water filtration technologies (World Bank, n.d.). Meanwhile, study also suggests that energy-efficient building retrofitting can contribute to both water and energy conservation while lowering greenhouse gas emissions (International Finance Corporation, 2021). It is worth for developing Asian countries to also be aware of the growing energy demand and look into energy efficiency, renewable energy, as well as waste-to-energy solutions for their urban water management.

Sustainable water management requires sustainable financing. For Singapore, this means the trade-off between water independence and affordability, as energy and technology costs grow. Singapore Government (n.d.) listed that it cost $1.3 billion SGD to operate the water system in 2015, which was three times more than in 2000. For developing countries in the region, ADB (2017) estimated an $800 billion USD climate adjusted investment needs for water and sanitation infrastructure from 2016-2030. Among current water investments, 98% came from the public sector (Asian Development Bank, 2017). This calls for the significant need to unleash private capital investment. Public-private partnership, green finance, blended finance are some of the ways to mobilize the private sector and bring in benefits such as cost reduction, asset management, and capacity building for water infrastructure financing (Bessadi & Cardascia, 2019; Cardascia, 2019). Meanwhile, as post-COVID recovery calls for more resilient cities, investing in climate-smart and nature-based urban infrastructure, such as wetlands, mangroves, and other green spaces, not only can provide urban flood protection and purify water supply, but also can bring positive socio-economic impacts, generating both investment and employment opportunities as well as improving quality of life (International Finance Corporation, 2021).

6.3. The role of international development agencies
International development agencies such as multilateral development banks are an important source for financing infrastructure. Like developing Asian countries, during the 1960s and 70s, the then under-developed Singapore received 14 loans from the World Bank, mostly focusing on infrastructure development, including projects to construct and improve water supply, sewerage systems, and water treatment plants (World Bank, n.d.). Both Phnom Penh and Dhaka, as well as other developing countries in this region, received loans, technical assistance,

and capacity building support from the Asian Development Bank (ADB) for improving their urban water utilities. Multilateral development banks can also help catalyze private sector investments through other financial instruments such as credit guarantee. ADB has recently opened its Singapore office to assist mobilizing private sector funding to infrastructure and social development projects in the region (Asian Development Bank, 2019).

International development agencies also contribute to better urban management through designing efficient projects incorporating these learnings. These include insisting on developing people and organizational skills, improving managerial capacity, introducing operations, maintenance and asset management practices, as well as efficient technology adapted to the context. This highlights the importance of knowledge sharing through papers and blogs as the present one. While financing water infrastructure projects, development agencies such as ADB are also harnessing valuable success and failing practices from different country contexts. Knowledge products such as Water Insecurity and Sanitation in Asia[8] as well as Asia Water Development Outlook [9] provide insightful performance indicators, evaluations, and recommendations for water management in Asia and the Pacific region. During the COVID-19 pandemic, agencies like ADB also provided post-COVID recovery guidance for cities, outlining the importance of ensuring smooth and pro-poor urban water operations in cities' immediate response actions, as well as continuing to invest in resilient and quality water supply and wastewater services in the longer term (Asian Development Bank, 2020a). Through documenting and sharing such knowledge and practices, international development agencies add values to policy, institutions, and infrastructure development for the region's secure water future.

7.   CONCLUSION

Singapore's urban water management has been bearing fruits thanks to its holistic planning, supply and demand management, as well as its constant efforts in technology advancement and innovation. Although Singapore's urban water management model is unique due to the country's political and geographical structure, developing countries in Asia and the Pacific region can still draw knowledge and practices from Singapore as well as other cities' experience. This includes learning from their successes such as institutional autonomy and people-centric management, inter-agency coordination, water demand management, tariff inclusiveness, NRW reduction and regulation, and innovations. It also means drawing lessons from Singapore's remaining challenges that are shared by cities in developing countries, including climate impacts, energy dependence, and the concern of financial sustainability. Meanwhile, by incorporating these learnings into infrastructure projects and knowledge products, international development agencies can play a positive role in facilitating better urban water management in the Asia and Pacific region.

This paper faced a number of limitations, include self-reported data from field trips and conversations with Singapore PUB senior officials, which could lead to biases; and potentially outdated information due to limited access caused by COVID-19. Building on these, future research can study ways to enhance water-related data availability and data infrastructure in urban water management, or dive into the financing aspect of urban water management and offer sustainable financing options for achieving water security in developing Asian and Pacific cities.

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[8] Water Insecurity and Sanitation in Asia: https://www.adb.org/publications/water-insecurity-and-sanitation-asia
[9] Asia Water Development Outlook: https://www.adb.org/publications/asian-water-development-outlook-2016

8.   ACKNOWLEDGEMENT

Annex: Reduce the energy cost of desalination through R&D

Singapore's desalination plants are still powered by national grids. At Tuas Desalination Plant, Singapore's 3rd desalination plant, while there are solar panels installed, the electricity produced is not yet enough to power the desalination process but only administrative use. PUB (2016) estimated if the technology maintains the status quo, desalination's energy consumption will quadruple in 2060.[10] In tackling this, PUB is currently researching on Electro-deionization technology, which adopts electric field to pull dissolved salts from seawater and demonstrates an achievable energy consumption of 1.65 kWh/m3 (PUB 2016). Another potential solution could be biomimicry, which mimicks biological processes such as mangrove plants filtering and extracting fresh water from seawater using almost zero energy. One biomimicry technology is the membrane enhanced by aquaporin, a type of protein that blocks salt when water is pushing in an out of cells. A research team at Singapore's Nanyang Technology University has proved that aquaporin-based membranes can save energy in wastewater treatment and is yielding promising results in applying the technology in enhancing RO process in desalination (Li, et al. 2019; Qi, et al. 2016).
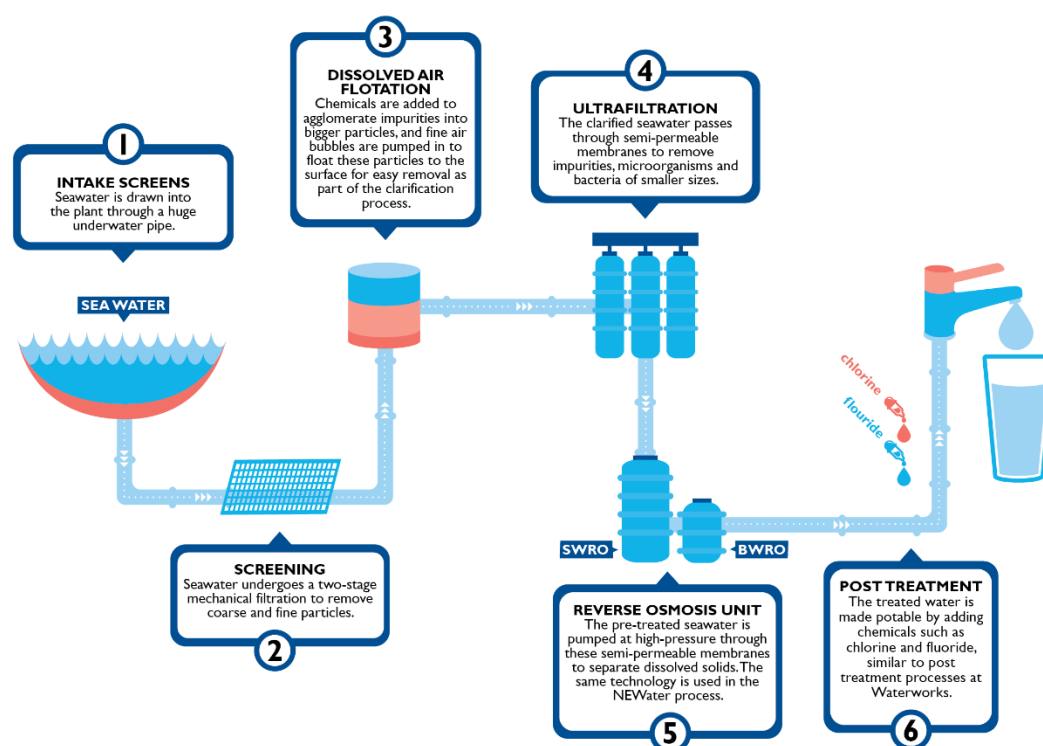

Figure 3 The desalination process at Tuas Desalination Plant, Singapore's 3rd desalination plant that can produce 30 million gallons of water per day (PUB)

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[10] Currently Singapore has three desalination plants, and two more to be finished building by 2020.

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SPATIAL DISTRIBUTION OF ROAD ASSETS IN INDIAN TOT AUCTIONS

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ABSTRACT

In March and December 2018, the Indian government auctioned two bundles of roads to monetize its assets using the Toll-Operate-Transfer (TOT) model. This paper focuses on understanding spatial distribution of monetized road assets for TOT I and II. Our hypothesis is that there are likely to be strategic reasons for the spatial distribution. The research design consists of comparative case studies of these two auctions. The data sources include in-depth interviews with bidders, government officials, and analysts as well as documentary analyses of concession agreements, bid documents, and other secondary data. It is found that road assets for TOT I were in "politically friendly" states with better asset quality to make them bankable and encourage private participation in future auctions. The bids were well above the reserve price. For TOT II, the assets were of lower quality and three highways out of eight in the auction bundle were in left-leaning opposition-controlled states. The reserve price was also higher, and unfortunately, the bids were too low, and the contract was not awarded.

Keywords: Asset Monetization; Asset Recycling; Auctions; Toll-Operate-Transfer Model

1. INTRODUCTION

Infrastructure development is a key driver of economic growth (Munnell, 1992; Queiroz, Haas, & Cai, 1994). However, India was ranked 70th out of 141 countries in terms of the quality of infrastructure (World Economic Forum, 2019), and 44 out of 167 countries in World Bank's Logistics Performance Index in 2018 (World Bank, 2018). An estimated investment of US$4.5 trillion is needed in infrastructure till 2040 to sustain its GDP growth (Economic Survey of India, 2018).

To meet this investment requirement, India needs to spend approximately 7% to 8% of its GDP annually. However, during 2014-20, the annual infrastructure investment was only about 4.5% of GDP (Economic Survey of India, 2020). Consequently, in the early 2000s, the government encouraged the private sector to invest into infrastructure projects by providing guarantees, tax breaks, and viability gap funding. Because of a weak bond market, the government also encouraged participation from private, state and shadow banks, which have contributed to approximately 80% of the total debt in infrastructure projects (Reserve Bank of India, 2020).

From 2002 to 2010, private sector investment in infrastructure grew annually at a rate of 70% but declined rapidly thereafter (World Bank, 2020). The decline is mainly attributed to problems such as land acquisition, contractual issues, poor governance, and delays in securing licenses, permits, and environment approvals.

Consequently, banks have become averse to lending in infrastructure projects (Bloomberg, 2018), and developers have also become wary of investing into greenfield PPP projects.

In response, the Indian Government has taken some initiatives such as developing the bond market and setting up infrastructure debt funds (IDFs), infrastructure investment trusts (InvIT), development finance institution (DFI), and National Investment and Infrastructure Fund (NIIF). It also provided financial support to revitalize the PPP model and improve the risk allocation. These initiatives have not proven adequate to revitalize investments into infrastructure sector. The debt markets also failed to take off as most of the infrastructure projects carry non-investment grade credit rating (Kumari & Kumar Sharma, 2017; Singh & Kathuria, 2016).

Arising from these setbacks, the Indian Government has recently experimented with long-term leasing of operational toll roads to the private sector based on the Toll-Operate-Transfer (TOT) model. If successful, this model will be extended to other types of infrastructure projects. The government has identified that US$40 billion can be unlocked through asset monetization by FY25 (Economictimes, 2021).

Under the TOT model, the National Highway Authority of India (NHAI) will auction its operational highways and collect funds upfront from winning bidders. The winning bidder has the right to collect toll revenues for 30 years. As the collected funds will be reinvested in new infrastructure projects, the success of TOT model is crucial for NHAI. Because of the government's fiscal constraints, NHAI currently obtains less than 10% of its annual funding needs through budget allocation (MoRTH Annual Report, 2020).

The TOT procurement route has attracted diverse investors because of the absence of construction risk. These investors include infrastructure funds, insurance companies, pension funds, sovereign wealth funds, O&M agencies, and tolling agencies. Infrastructure as an asset class provides stable long-term returns that are not correlated with other asset classes. This paper investigates the rationale for the spatial distribution of toll road assets that were monetized during the first and second auctions in 2018. In particular, we seek to uncover if there are strategic reasons for the spatial choice of road assets.

The paper is organized as follows. Section 2 reviews the literature and develops our hypothesis on the spatial choice of road assets for the two auctions. Section 3 provides the research methodology, followed by the data analysis. The final section concludes the paper.

2. FACTORS AFFECTING THE SPATIAL DISTRIBUTION OF TOLL ROADS

2.1. Asset quality

For each bundle of road assets, quality depends on road capacity and condition, mix of assets, proximity to each other, connectivity with surrounding infrastructure, competing modes of transport, current usage, and regional growth potential. High quality assets tend to reduce revenue risks and attract more bidders. The higher bids will raise government revenues.

In the case of proximity, it is easier to manage road assets that are close to one another to achieve economies of scale, such as in bundling operation and maintenance contracts, procurement of materials, and training of workers. It is difficult to sell poor quality assets even cheaply. The high uncertainty in asset quality results in lower bids because of perceptions of "lemons" (Akerlof, 1970). Markets can also fail in repeat low quality asset sales; that is, it will not attract bidders (Kollock, 1994).

2.2. Political factors

In federal democratic states like India, political support from state and local governments is crucial for implementing central government policies. The opposition parties that rule the lower

levels of government may not support asset monetization if they do not benefit from it. Hence, the central government has several options: it may proceed by central command, incentivize the lower levels of government such as through revenue sharing, or select projects that are not in opposition wards.

Beyond the public sector, the central government may use project auctions to gain support from the private sector by providing opportunities to operate the assets (Khemani, 2012; Kitschelt & Wilkinson, 2007; Mei & Moses, 2005). The private sector may also seek "rents" (Krueger, 1974) by influencing the auction structures to their benefit, such as by excluding other bidders through favourable qualifying criteria and providing better contract terms. Finally, politicians and bureaucrats may further their own interests by selecting projects that increase political support or enhance public careers.

2.3. Social factors

Although many governments invest in infrastructure to provide greater access for the poor, the bigger challenge is often user affordability. Consequently, the central government is less likely to select projects in poorer regions for lack of revenues and potential resistance. Similarly, it will try to avoid left-leaning southern Indian states where labour unionization is strong (Evans, 2017; Ramaswamy, 1976). Workers in these regions tend to be suspicious of private enterprise when it comes to delivery of infrastructure because of the profit motive and land acquisition (Ortiz & Buxbaum, 2008).

2.4. Strategic factors

Governments tend to auction their most profitable assets in early stages of asset monetization to ascertain private sector interest and attract more bidders in subsequent auctions (Asensio, 2009). They may also use road auctions to promote regional development. If the auctioned roads are well maintained, they will open new markets by improving access and logistics.

Finally, governments may also use road auctions to reform the public sector by introducing competition, new management practices, and private sector efficiencies. In some cases, it is also possible to use privatization to curb union power (Solomon, 2009).

3. METHODOLOGY

This study uses a comparative case study design to analyse the spatial distribution of auctioned toll roads. The "comparative" part does so by investigating commonalities and differences between cases, and the "case study" part probes for insights and rationale behind geographical spread of assets. Similar research (Annamalai & Hari, 2016; Solheim-Kile & Wald, 2019, 2020; Villani, Greco, & Phillips, 2017) also used comparative case studies.

The auctions for TOT projects were chosen because they were the first two cases of such auctions in India, and little is known about the rationale behind the spatial distribution of assets in such auctions. Further, the success of TOT auctions is crucial for Indian government due to fiscal constraints. It is unfortunate that the second auction was annulled, resulting in the loss of opportunity to monetize the road assets.

The first and second auctions comprised of nine and eight highway stretches respectively, and each group is bundled as a single bid. Details are given under the "Comparative Case Studies" section. The primary data were collected through in-depth interviews with bidders, government officials, and analysts using semi-structured questionnaires. The responses were coded and used to develop themes and a coherent narrative to probe into the rationale behind spatial distribution of assets. The sample includes seven government officials/government consultants, seven analysts (credit rating agencies, financial, technical, and legal advisors, insurance providers, and

other industry experts), and four project lenders. Hence the sample is size is eighteen, comprising six officials directly involved in structuring the TOT auctions and twelve industry experts.

The secondary data comprised concession agreements, bid documents, press statements, websites, and scholarly articles. Any confidential information not accessible through primary and secondary data collection were obtained as per "Right to Information" Act of the Government of India (GOI). The data were used for analysing the asset quality, auction design, political, social, and strategic factors that determine the spatial distribution of the toll roads.

4. COMPARATIVE CASE STUDIES

4.1. Background: Highway Financing in India and the Need for Asset Monetization

The National Highway Authority of India (NHAI) is a government of India's autonomous agency responsible for the development, maintenance, and management of federal highways in India. NHAI's revenues accrue from internal and external sources. The internal sources comprise of toll proceeds, fuel cess, and road tax on new vehicle registrations. The external sources of funds include market borrowings, private investment, and budgetary support. The major expenses include land acquisition, greenfield construction, debt servicing, as well as payments of grants and annuity. A detailed breakdown of the revenue and expenditure of NHAI for FY20 is shown in Figure 1.
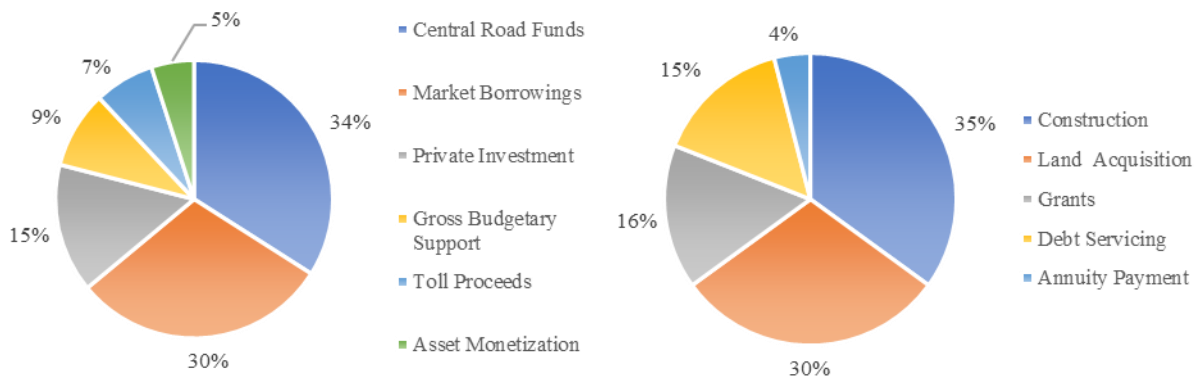
Figure 1 NHAI's sources of funds and expenditure. Source:(MoRTH Annual Report, 2020).

NHAI is heavily reliant on market borrowings and private investment because the internal sources of funds and budgetary support are not sufficient. The market borrowings over last few years have increased drastically because of decline in private investment and increased expenses. The expenses such as grants and annuities rose during Modi government's first term because of the decline in private investment and the consequent need for government support to improve bankability. Further, land acquisition costs have increased 4.5 times from 2014 to 2018 due to the implementation of new Land Acquisition Act of 2014. Finally, increased borrowings have led to a spike in debt servicing expenses (MoRTH Annual Report, 2020).

Faced with these constraints, the GOI plans to generate funds by monetizing its operational assets. It has estimated that US$40 billion can be unlocked by FY 25 through monetization of its highways with proven toll collection record (Economictimes, 2021).

4.2. Experiment with Toll-Operate-Transfer (TOT) Model for Asset Monetization

NHAI introduced the Toll-Operate-Transfer (TOT) model in 2018 where it will auction its operational highways and collect funds upfront from the winning bidders. The winning bidder

will get the right to operate the roads and collect toll revenues for a period of 30 years. The government will reinvest the collected funds in new infrastructure projects. The auction requires the approval of cabinet committee on economic affairs (Figure 2).
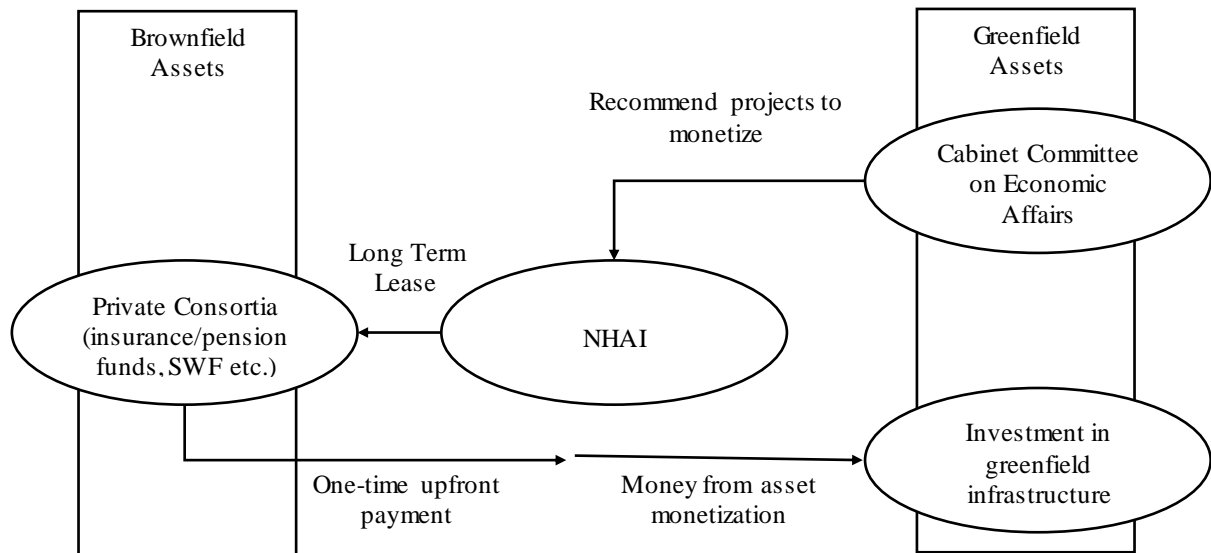

Figure 2 TOT model for infrastructure development in India. Source: (MoRTH, 2016)

The TOT procurement has attracted many investors because of the absence of construction risk. The investors include infrastructure funds, insurance companies, pension funds, sovereign wealth funds, O & M agencies, and tolling agencies (CRISIL, 2019).

4.3. Spatial Distribution of Toll Roads in TOT Auctions

The spatial characteristics of the assets in TOT I (first auction) and TOT II (second auction) are given in Table 1.

Table 1 Characteristics of the assets in both auctions. Source: Tender documents by NHAI.

Characteristics	TOT I	TOT II
Total length (km)	681	587
Number of highways stretches	9	8
States where the toll roads are located	Gujarat and Andhra Pradesh	Gujarat, Rajasthan, Bihar, and West Bengal
Passenger car unit (PCU)/km	512	251
Expected growth rate in traffic	10%	8%
Expected maintenance cost per km (US$m)	0.18	0.14

4.3.1. Asset quality

The highways in TOT I states are well connected to economic corridors, industrial clusters, consumption centres, and ports. The quality of existing infrastructure in all Indian states is highlighted in form of color-coding in Figure 3 based on the good governance index for year 2019 by National Institution for Transforming India. The darker the state in Figure 3, better is the quality of existing infrastructure, utilities, and regional connectivity. Six out of nine auctioned highways are part of the Golden Quadrilateral connecting four major Indian cities, namely, Delhi, Mumbai, Chennai, and Kolkata. These highway stretches are also close to each other, making it easier to manage and share resources.

The highways in TOT II are in states with lower economic growth potential and per capita income (CRISIL, 2019). These highway stretches are dispersed with no spatial synergy across assets other than portfolio diversification.
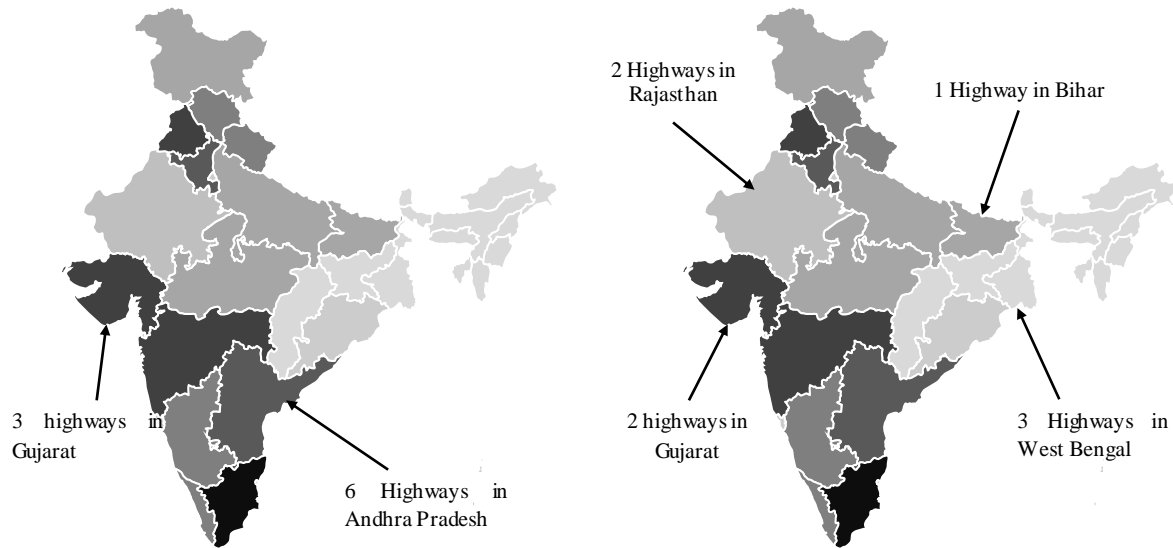
Figure 3 Geographical Spread of Highways in TOT I (left) and TOT II (right).

4.3.2. Political factors

The ruling Modi government from the right-winged Bhartiya Janata Party (BJP) also governs the TOT I states. Gujarat is ruled by BJP and Andhra Pradesh is ruled by a BJP ally. However, in case of TOT II, the three highways in West Bengal are in left-leaning opposition territory. The TOT I states have historically exhibited low levels of political competition and electoral volatility as compared to the TOT II, as seen from the average tenure of Chief Ministers (Figure 4). The TOT I states are also better governed (Figure 4), based on the Public Affairs Index 2020 which ranked all the Indian states on metrics such as growth, equity, and compliance with sustainable development goals (Gollerkeri, 2020). Further, TOT I poses fewer political risks as compared to TOT II because only two states are involved, instead of four in TOT II.
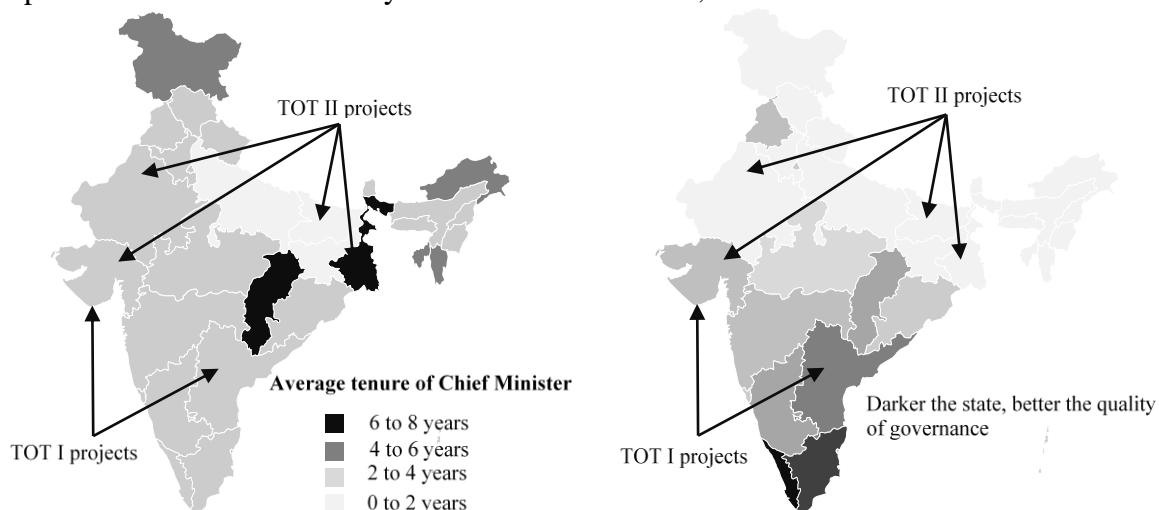
Figure 4 Difference in political stability and governance in states. Source: (Gollerkeri, 2020)

There is no evidence that the NHAI selects TOT projects to favour certain private investors. It is a puzzle why the opposition-controlled state of West Bengal was selected in TOT II. It may be an experiment to test the ground sentiment in opposition states.

4.3.3. Social factors

TOT I states have better user affordability as compared to the TOT II states because of higher per capita income. Consequently, the revenue collected per km from the tolled roads were higher for TOT I states as compared to TOT II states (Ministry of Road Transport & Highways, 2018). TOT II projects are also more susceptible to public resistance as compared to TOT I due to the presence of strong labour unions and history of left-leaning politics in TOT II states.

### 4.3.4. Strategic factors

The GOI auctioned its most profitable assets in TOT I to ascertain private sector interest and attract more bidders in subsequent auctions (CRISIL, 2019).

To this end, the government excluded competing routes in the bid documents and chose assets in the least corrupt and most business-friendly states. Based on the India corruption survey carried out by Transparency International India in 2019, TOT I states were ranked among the least corrupt states whereas TOT II states were among the most corrupt states in India. The World Bank also ranked TOT I states higher than TOT II for ease of doing business (Figure 5).
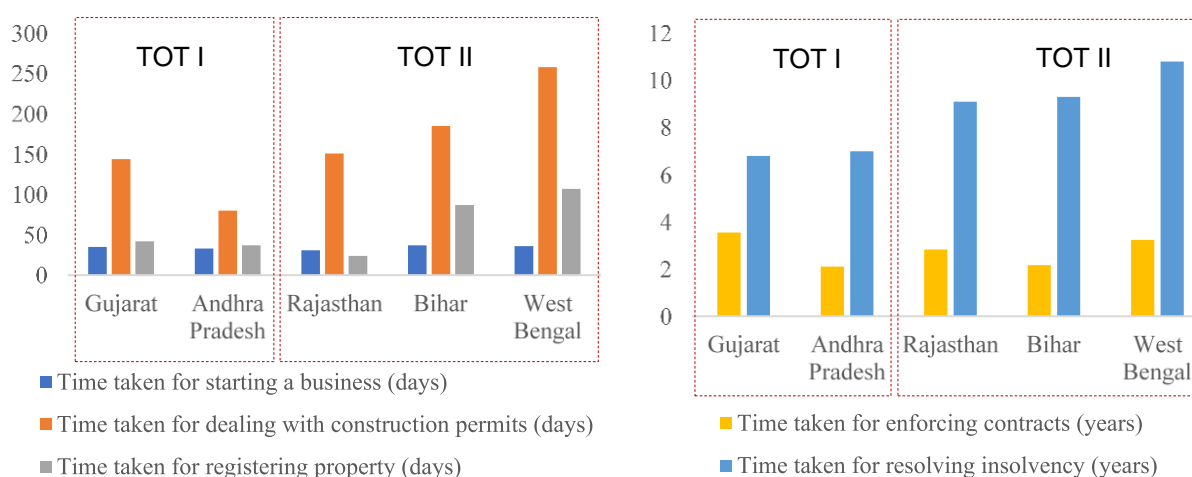
Figure 5 Ease of doing business in the states of TOT I and TOT II. Source: (World Bank, 2019)

To attract foreign investors who can commit large upfront payment to reduce the fiscal stress of NHAI, the government decided to bundle large sections of highways across various states with proven record of toll history. The financial closure was achieved for TOT I in August 2018 and the government plans to reinvest the auction proceeds for regional development.

4.4. Responses to TOT I and II Auctions

The response to TOT I auctions was better than expected because the winning bid of INR 9282 crores (US$1.38 billion at the prevailing exchange rate) by the Macquarie group was well above the reserve price of INR 6258 Crores (US$0.89 billion at the prevailing exchange rates). There were four bids from different consortiums, each comprising a mix of local and international investors (Figure 6)

There were three bids for TOT II. The bidders were similar to that of TOT I (Figure 6). Unfortunately, bids for TOT II auction were well below the reserve price of INR 5362 Crores

(US$0.77 billion at the prevailing exchange rates), and the contract was not awarded. All bids in TOT I were above the reserve price, whereas in TOT II, all bids were below the reserve price. Also, greater number of companies attended pre-bid meetings before TOT I auction as compared to TOT II.
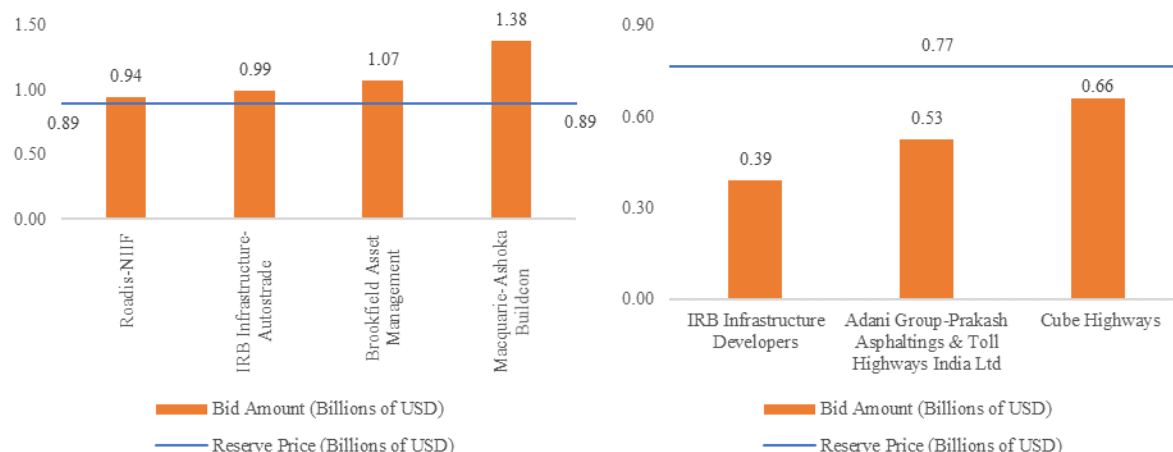
Figure 6 Auction results for TOT I (left) and TOT II (right). Source: (NHAI, 2019).

A diverse set of bidders participated in both the auctions. Such bidders included infrastructure funds, insurance companies, pension funds, sovereign wealth funds, O & M agencies, and tolling agencies (Figure 6). The heterogeneity amongst the bidders in terms of different core competencies, business models, and bidding objectives may have contributed to the spread in bids as observed in both the auctions (Figure 6).

6. DISCUSSION

The low bids in TOT reflect the lower asset quality. However, if the profit rate remains the same in the two auctions, lower asset quality and per capita income are not barriers to profitability. Hence, the lower bids may reflect a higher reserve price because of the high bids in TOT I or perceptions of higher risks in TOT II. The higher risks may be due to different economic conditions at time of bid, road assets are in opposition states, differing tender information quality, different bidding objectives, and the presence strong labour unions. A summary of the two auctions is given in Table 2.

From our interviews, we discovered that the government authorities set higher reserve price to avoid public scrutiny and allegations of selling the family silver to friendly business houses cheaply. The officials cited the coal and 2G spectrum auctions during the second term of Manmohan Singh's government when several cabinet ministers and bureaucrats were prosecuted based on allegations of selling public assets cheaply. The auction outcome of TOT I further influenced NHAI's decision to set up high reserve price for TOT II as the winning bid in TOT I was 55% more than the reserve price.

The interviewees also indicated that India faced a liquidity squeeze after the bankruptcy of a specialized financial institution, the Infrastructure Leasing & Financial Services (IL&FS) in September 2018. It led to the financial crisis in shadow banking sector. Consequently, the cost and availability of funds for the bidders were not same in TOT I and TOT II, because the financial crisis occurred during the period between the two auctions. However, when NHAI revealed the computation of the reserve price to potential bidders, it did not factor in the rising cost of funds and credit rationing.

Table 2 Summary of the two auctions.

	TOT I	TOT II
Asset quality	Higher traffic density, better road quality, and proximity of assets.	Lower traffic density, lower road quality, dispersed assets
Political factors	The ruling BJP party controls both the central and state governments where roads were auctioned.	3 out of 8 stretches of highways were located in the left-leaning state of West Bengal.
Social factors	States with higher per capita income.	Poorer states with strong labour unions.
Strategic factors	Auctioned the most profitable assets to ascertain private sector interest and attract more bidders in subsequent auctions.	Auctioned lower quality of assets in view of high bids in TOT I.
Outcome	High bids	Low bids

6. CONCLUSIONS

This paper examined the factors that affect the spatial distribution of the toll roads in auctions for long-term leasing of Indian toll roads using the Toll-Operate-Transfer (TOT) model. In TOT I, NHAI selected the most profitable routes in government-controlled states to ensure its initial success as a strong signal for subsequent auctions.

In TOT II, NHAI experimented with lower quality routes and three out of eight highways were in left-leaning opposition-controlled states. The bids were below the reserve price. We interviewed diverse stakeholders and found out that the bidders perceived that the reserve price was set too high and projects were too risky during TOT II because of different economic conditions at time of bid, road assets are in opposition states, differing tender information quality, different bidding objectives, and the presence strong labour unions.

These findings highlight the importance of political considerations and experimentation in selecting auction assets. It appears that auctions in government-controlled states tend to produce more favourable outcomes, based on the first two TOT auctions to date. We intend to study future TOT auctions planned over the next few years (MoRTH Annual Report, 2020) to better understand the choice of assets and draw more general conclusions.

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SCIENTOMETRIC REVIEW OF RESEARCH TRENDS ON PUBLIC PRIVATE PARTNERSHIP (PPP) FOR INFRASTRUCTURE PROJECTS FROM 2000 TO 2020

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ABSTRACT

In the construction industry, public-private partnership (PPP) has been becoming increasingly common. While real-world PPP for infrastructure projects have been reported in many journals, published work on systematically summarizing what they have already provided remains limited. Based on the 1749 publications on PPP for infrastructure collected from the Scopus database for the period of 2000-2020, this study conducted a scientometric analysis in terms of annual publications, regional distribution, active contributors, published journals, co-occurrence keywords, and main research themes of previous studies. This paper found that there was a significant increase in the number of publications on PPP for infrastructure since 2008. Researchers from the USA, China, and Australia have been the main contributors to this research area. In addition, four main themes of research on PPP for infrastructure are explored, and several research gaps and research directions in this area are established for further studies.

Keywords: PPP; infrastructure project; scientometric; analysis; network

1. INTRODUCTION

Internationally, the use of public-private partnership (PPP) as a strategy for implementing infrastructure projects is well known. In the last few decades, the use of PPP as a major method of delivering infrastructure projects has grown significantly (Al-Saadi & Abdou, 2016; Alfen et al., 2009; Li et al., 2005). PPP is a strategy for the economic value of infrastructure outputs, and it covers a wide range of public-sector infrastructure (Cui et al., 2018). Access to private funding for expanding services; better risk management and allocation; clearer project objectives; new concepts and flexibility; better preparation and increased incentives for competitive tendering; and greater value for money for infrastructure projects can all be demonstrated in terms of the PPP approach's planned benefits (Al-Saadi & Abdou, 2016). There has been a proliferation of schemes encouraging public-private sector collaboration to improve infrastructure through a broad variety of economic activities (Ullah et al., 2016). PPP agreements have been adopted by governments in many countries. Concerns over government spending are one explanation for this trend. These structures are viewed as a key component of modernizing public services, with the aim of improving their quality and performance (Carbonara et al., 2014).

Along with the rapid growth in PPP applications, research interest in the field has exploded in the last two decades, resulting in a substantial increase in the number of published papers as well as a wide range of research subjects, domains, and methods.

As the academic research on PPP for infrastructure has grown, researchers have been able to share research results and examine the status quo and trends in PPP practice. As a result, this review of scientific papers published in academic journals will aid researchers in discovering the current status and future trends of the chosen topics in this domain (Cui et al., 2018; Yongjian Ke et al., 2009; Osei-Kyei & Chan, 2015).

Further studies will benefit from the integration and classification of published literature reviews within the PPP for infrastructure domain because it will enable them to gain a better understanding of the subject and perform related research more intensively and efficiently. Hence, it is critical to summarize the global trends of PPP for infrastructure through comprehensive analysis and to propose new research directions. In this regard, this paper performs a systematic analysis of studies on PPP for infrastructure in the years from 2000 to 2020 with the following derived objectives:
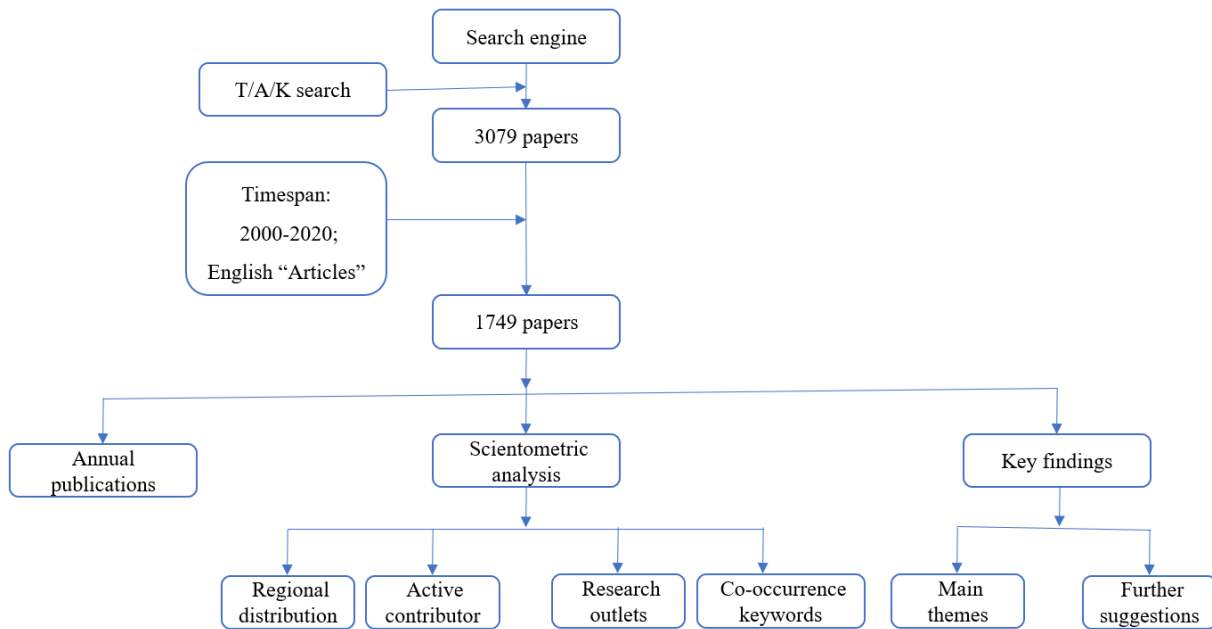
- To ascertain the annual publication trends of PPP for infrastructure from 2000 to 2020
- To identify countries with the most published papers on PPP for infrastructure from 2000 to 2020
- To identify author's contribution in studying PPP for infrastructure from 2000 to 2020
- To summarize, compare, and contrast the key findings of publications on PPP for infrastructure from 2000 to 2020

2.   RESEARCH METHODOLOGY

This paper aims to comprehensively review PPP for infrastructure in the scientific literature by using scientometric analysis. The author uses VOSviewer software based on the bibliographic data collected from Scopus. In this study, the scientometric review was done using the science mapping technique. This method is commonly used for domain analysis and visualization of important patterns and trends in the body of knowledge (Chen, 2017; Cobo et al., 2011). It gives valuable information about the research context in the field of consideration (Cheng et al., 2018; L. Zheng et al., 2019).

One of the decisions researchers must make when conducting an overview of a science area, such as this paper, is which scientific databases to use (Olawumi & Chan, 2018). Scopus, ISI Web of Science, Dimensions, Google Scholar, and Research Gate are the main research databases. Because of extensive coverage of high-quality peer-reviewed papers, stringent inclusion criteria and indexing procedure, and availability of more recent publications, the Scopus database was chosen for identifying relevant literature on PPP for infrastructure in this study (Zhao et al., 2019). The search string, a systematic literature search, retrieval, and indexing were performed on Scopus search engine or database using the search query "PPP" and "infrastructure" or "public-private partnership" and "infrastructure" in the "title/abstract/keyword" section of published studies. The preliminary search was not limited to a particular country and no year limitation; the output was 3,079 publications.

Next, the "source title" has been used to refine to be considered during the period between 2000 and 2020; and only articles and reviews written in English were chosen. Final, to ensure that the findings of the literature review were systematic and accurate, the literature consulted was limited to articles, excluding book reviews, letters, news reports, and conference abstracts. This is because journal articles are generally peer-reviewed and are believed to provide more detailed, robust, and high-quality knowledge than other forms of publications (Z. Liu et al., 2019). In total, 1749 publications on PPP for infrastructure were collected after refinement and duplicate testing, and all bibliographic material was exported from Scopus, forming the dataset for further analysis in this study. Figure 1 illustrates the research framework for this study.

Figure 1 The research framework for the study

3. RESULT AND DISCUSSION

3.1. Annual Publications on PPP for Infrastructure from 2000 to 2020

The temporal distribution of all 1749 publications on PPP for infrastructure obtained from the Scopus database is provided in Figure 2. The number of research publications related to PPP for infrastructure has increased steadily in the years 2000-2020, with a sharp increase particularly since 2018. This proves the gradual rising of interest in exploring the best ways of delivering PPP for infrastructure projects since its evolution. Furthermore, the findings statistics support the claim that PPP for infrastructure research is one key domain of interest to academic researchers (Yongjian Ke et al., 2009; Tang et al., 2010).

A total of 1578 papers on PPP for infrastructure were published in the period of 2008-2020. These figures are also unsurprising because, after the global economic crisis of 2008, many governments were pressured to introduce PPP policies, causing a greater emphasis on how this strategy could be applied efficiently and successfully to reduce a country's infrastructure deficit (Kappeler & Nemoz, 2010). It is important to note that the pattern of increased research on PPP for infrastructure will continue, as more policymakers embrace and adopt this approach as a result of its success in other jurisdictions (Junxiao Liu et al., 2015). Furthermore, the number of PPP for infrastructure projects is rising around the world, which will certainly stimulate more research into this field in order to implement potential projects.
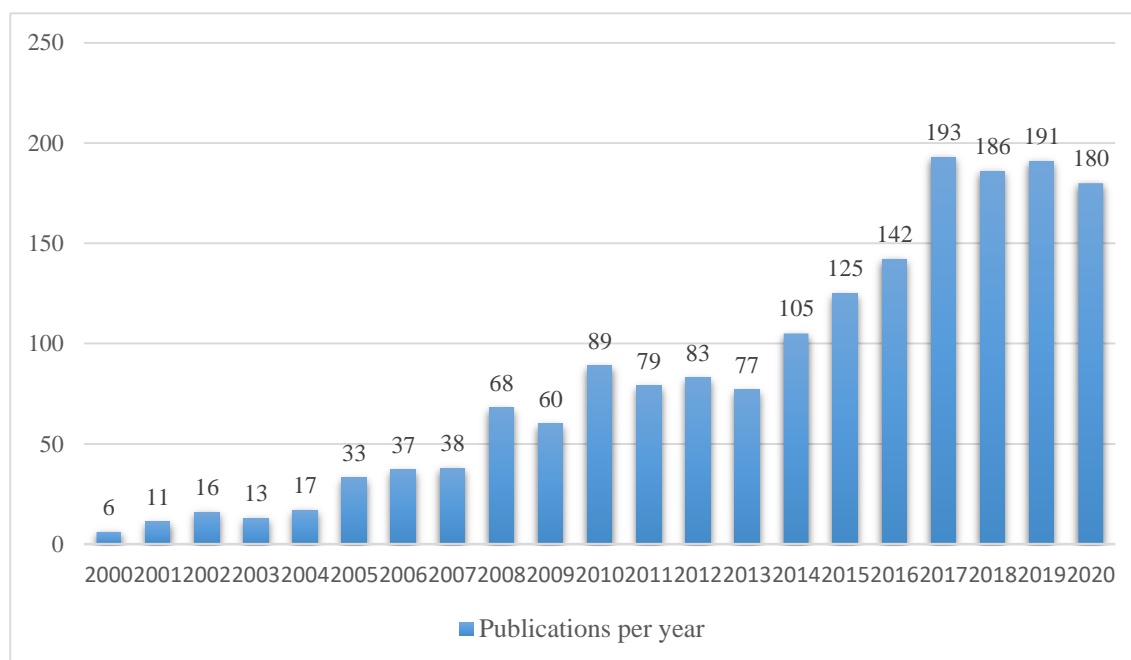
Figure 2 Annual publication on PPP for infrastructure research from 2000 to 2020

3.2. Regional Distribution of PPP for Infrastructure Research from 2000 to 2020

The country/territory details in papers on PPP for infrastructure can be found in the published bibliographic records, enabling the key country/territory of the publications to be determined. 1749 PPP for infrastructure papers is written in 139 countries/ territories, according to Scopus database. Table 1 lists the top ten most active countries/territories in this are research. In terms of the overall volume of PPP for infrastructure papers, publications in the Top 10 countries/territories accounted for roughly 78 percent of the total volume. The top three nations, the USA, China, and Australia, each contributed 361, 180, and 172 articles, accounting for nearly half of the total number. This implies a widespread knowledge of PPP among researchers in these countries due to their well-implemented and well-developed PPP policy (Osei-Kyei & Chan, 2015).

Setting the minimum number of country documents and citations to 5 and 12, respectively, generated Figure 3. Of the 139 construction productivity research countries, 55 met the thresholds. It should be noted that the USA node was the biggest, implying that the USA academics were the primary contributors to the analysis of PPP for infrastructure.

In the years 2000-2020, China, India, and Hong Kong, three Asian countries/territories in the Top 10, accounted for roughly 30% of all publications in this domain. There were 152 publications in the United Kingdom, 104 publications in the Russian Federation, 59 publications in Italy, and 58 publications in Spain, accounting for approximately 21% of all publications in Europe. In North America, 361 papers were published in the United States and 86 in Canada, accounting for roughly 26% of the number. Australian academics published 172 papers in Oceania, accounting for approximately 10% of the number in this are research.

Table 1 Most contributing country/territory on PPP for infrastructure research from 2000 to 2020

Country	Documents	Citations	Ave. Citations	Total link strength
United States	361	3895	10.79	46854
China	180	2957	16.43	57795
Australia	172	3932	22.86	59124
United Kingdom	152	2738	18.01	35299
India	127	756	5.95	16114
Russian Federation	104	227	2.18	3392
Canada	86	1175	13.66	12276
Hong Kong	67	2261	33.75	31663
Italy	59	658	11.15	13204
Spain	58	559	9.64	14176
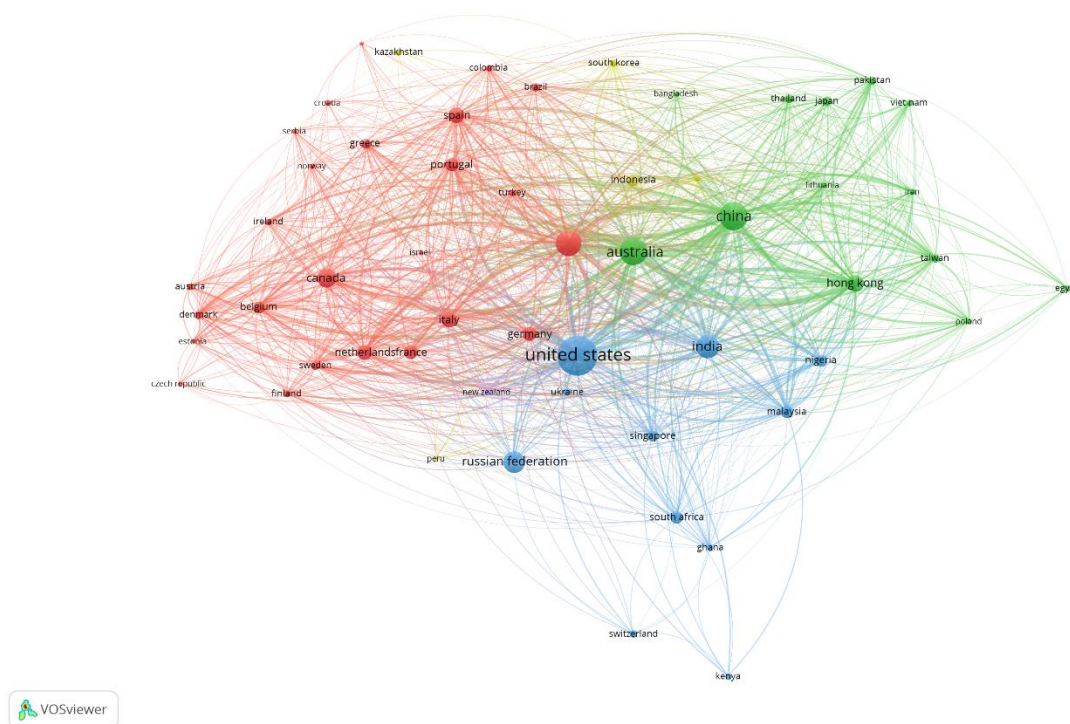
Figure 3 Country/territory distribution of on PPP for infrastructure research from 2000 to 2020

3.3. Active Contributors to PPP for Infrastructure Research from 2000 to 2020

According to the Scopus database, a total of 3,684 authors participated in PPP for infrastructure studies. The minimum number of publications and citations for each author has been set at 5 and 13; as a result, 54 of the researchers meet the threshold. The density visualization of the most productive authors network was shown in Figure 4. The diversity in the location of published authors shows that PPP for infrastructure research is global. The network shows the authors have published the highest publications on this domain such as Chan, A.P.C, Marques, R.C., and Liu, J. who are often researchers with influential works in PPP for infrastructure research domain.

Table 2 Authors with highest publications on PPP for infrastructure research from 2000 to 2020

Author	Documents	Citations	Ave. Citations	Total link strength
Chan, A.P.C	26	1122	43.15	11506
Marques, R.C.	20	711	35.55	3613
Liu, J.	19	515	27.11	11864
Smith, J.	17	503	29.59	13584
Love, P.E.D.	17	538	31.65	13350
Cruz, C.O.	16	430	26.88	2849
Zhang, L.	14	94	6.71	2245
Zhang, X.	14	987	70.50	1475
Siemiatycki, M.	14	362	25.86	2529

This finding was supported by the result statistics in Table 2, Chan, A.P.C is the most productive researcher on PPP for infrastructure area, with 26 publications and 1122 times cited, representing average normalized citation is 41.15 for each publication. Followed by Marques, R.C., and Liu, J. at 20 and 19 publications, respectively. Besides, 7 other researchers published at least 14 publications on PPP for infrastructure research area.
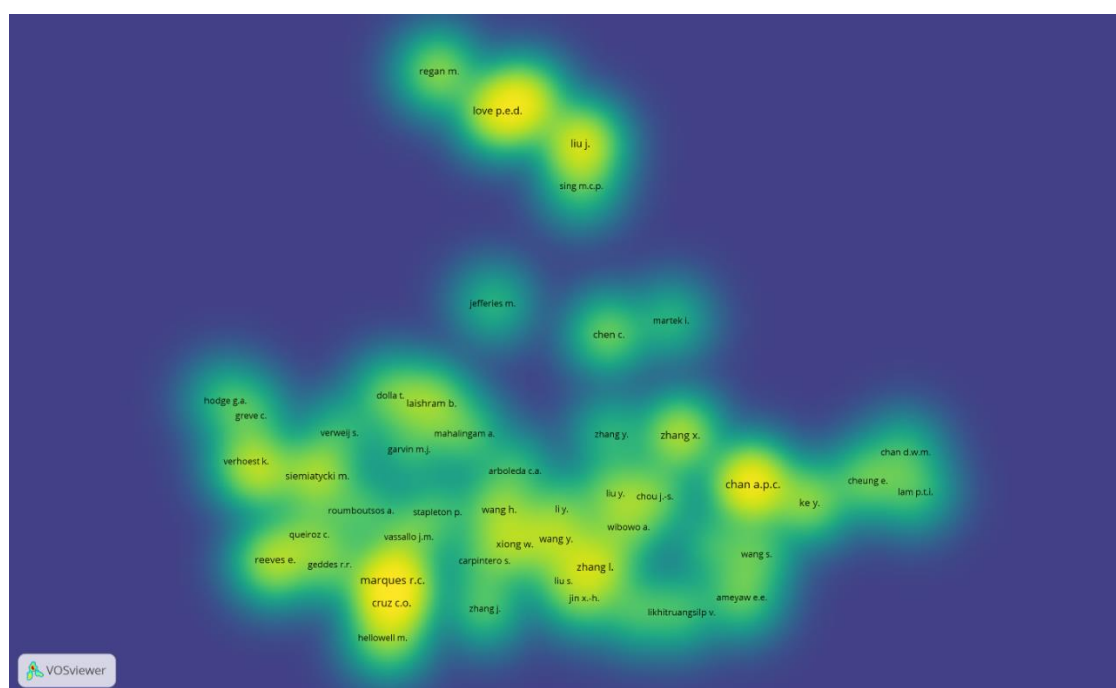
Figure 4 Most productive authors

The analysis was further used to highlight the affiliated authors' institutions. The exercise summarized the contribution of the various institutions to the development of the PPP or infrastructure during the study period. As provided in Table 3, Hong Kong Polytechnic University, Universidade de Lisboa, and Curtin University are leading the race with 36, 31, and 27 publications, respectively.

Table 3 Organizations with highest publications on PPP for infrastructure research from 2000 to
2020

Affiliation	Publications
Hong Kong Polytechnic University	36
Universidade de Lisboa	31
Curtin University	27
Instituto Superior Técnico	26
Universiteit Antwerpen	21
University of Melbourne	21
University of Toronto	19
Universidad Politécnica de Madrid	17
Bond University	17
The University of Hong Kong	16

3.4. Science Mapping of Academic Journals

Academic journals play an important role in the dissemination of research outcomes, hence, in
the review of the research trend, and it is essential that prominent research journals in the
domain are discovered. It is not a matter of promoting journals, but of informing researchers of
leading outlets and platforms to disseminate the findings of their research in order to achieve
maximum impact in both academia and industry (Osei-Kyei et al., 2020). The top 10
journals/proceedings in the area of PPP for infrastructure research are presented in Table 4. In
addition, a network analysis of these prominent journals/proceedings is shown in Figure 5
which illustrates 34 journals/proceedings with a minimum of 5 articles and 10 citations among
146 different sources from the retrieved Scopus database. Indeed, the large number of journals
identified clearly show how relevant PPP has become to infrastructure issues in contemporary
times.
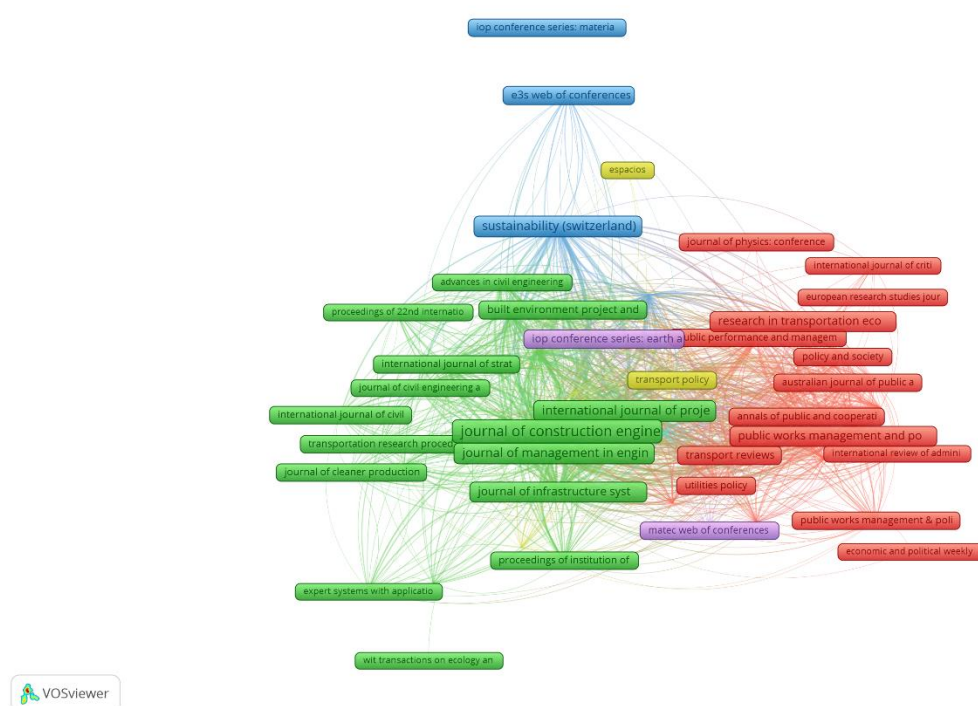
Figure 5 Network of landmark research outlets in PPP for infrastructure research from 2000 to
2020

As demonstrated in Table 4, Journal of Construction Engineering and Management has produced the highest number of articles on issues relating to PPP for infrastructure area, with 41 publications cited 2422 times, representing 50.97 citations per paper. It is followed by International Journal of Project Management, Sustainability (Switzerland), and Journal of Management in Engineering with 28, 26, and 25 publications, in turn. It should be noted that the articles retrieved for this analysis are only those related to the infrastructure PPP as used in the search engine. However, the results are an indication of the leading journals/proceedings in this field and its associated research areas.

Table 4 Most frequently publication journals/proceedings PPP for infrastructure research from 2000 to 2020

Source	Documents	Citations	Ave. Citations	Total link strength
Journal of Construction Engineering and Management	41	2422	59.07	5466
International Journal of Project Management	28	2084	74.43	5678
Sustainability (Switzerland)	26	179	6.88	3315
Journal of Management in Engineering	25	723	28.92	6315
Journal of Infrastructure Systems	21	394	18.76	4111
Public Works Management and Policy Advances in Public Private Partnerships	19	157	8.26	2299
Proceedings of the 2nd International Conference on Public Private Partnerships	18	7	0.39	1018
Research in Transportation Economics	16	222	13.88	532
Engineering Construction and Architectural Management	15	265	17.67	2828
IOP Conference Series Earth and Environmental Science	15	275	18.33	2691
Journal of Financial Management of Property and Construction	15	10	0.67	578
Built Environment Project and Asset Management	14	169	12.07	1956

3.5. Co-occurrence Network of Keywords

The keywords of the academic paper reflect its core content and the development of research topics can be achieved through a bibliometric analysis of these keywords (C. Zheng et al., 2020). As shown in Figure 5, each keyword node consists of cross-rings, and the rings and links are indicated in a spectrum of colors corresponding to the years of the keywords during the period under study. 1749 considered PPP for infrastructure documents contain a total of 8242 keywords and the minimum occurrences of keywords were set to 15 to avoid the visualizing of less relevant keywords. Only 163 keywords meet the set threshold, and these were visualized in Figure 6.

It is evident that "public-private partnerships" was the largest point of the research direction, showing that this keyword was mostly used in this field. In addition, the details of keywords that have frequently occurred in the analyzed documents illustrated in Table 5. According to the occurrences of the keywords, we can be aware that "infrastructure", "PPP", and "public private partnership" were also included in the popular research topics. Awareness of the most active

keywords should guide researchers on the appropriate keywords to be used in their articles in order to facilitate wider indexing and retrieval of articles.

Table 5 Most active keywords in PPP for infrastructure research

Keyword	Occurrences	Total link strength
public-private partnerships	199	250
infrastructure	158	341
PPP	93	159
public private partnership	80	100
public private partnerships	47	78
public-private partnerships	46	81
procurement	45	127
public-private partnership (PPP)	45	53
partnership	39	103
risk management	36	88
china	36	83
infrastructure projects	33	65
governance	32	70
developing countries	30	59
public-private partnership	30	40
India	29	54
risk allocation	27	64
partnerships	25	90
private sector	25	79

Figure 6 Co-occurrence network of keywords
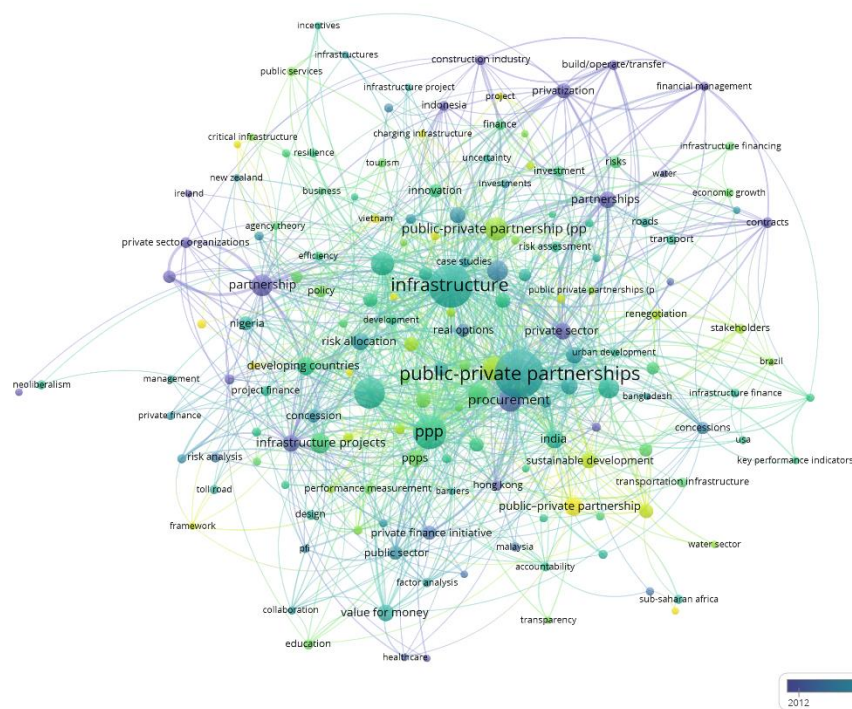
3.6. Main Research Themes of PPP for Infrastructure

This section will discuss the emerging domains and themes in PPP for infrastructure research. The themes were derived by analyzing the abstracts of the analyzed articles as well as the checklist of keywords derived from the bibliometric data. As a result, four main themes of research on PPP for infrastructure were identified as follows:

3.6.1. Research on success factors of PPP for infrastructure projects

Since the evolution of PPP, researchers have used the concept of success factors to improve understanding and best ways to implement PPP policies for infrastructure development (Aerts et al., 2014; Cheung et al., 2012; Chou & Pramudawardhani, 2015; Hwang et al., 2013; Jefferies, 2006; Y Ke et al., 2009; Li et al., 2005; Junxiao Liu et al., 2015; Olusola Babatunde et al., 2012; Tiong et al., 1992; Zhang, 2005). In fact, attention has also been paid to developed and developing countries using PPP policies to support infrastructure growth; critical success factors (CSFs) for implementing PPP projects in these countries have also been explored by researchers (Osei-Kyei & Chan, 2015).

For instance, the study of Cheung et al. (2012) analyzed the perceptions of respondents from Hong Kong, Australia, and the UK on the importance of 18 success factors which contribute to delivering successful PPP projects. This comparison showed that amongst the top five success factors ranked by Hong Kong respondents, three were also ranked highly by the Australians and British. These success factors included: "Commitment and responsibility of public and private sectors"; "Strong and good private consortium"; and "Appropriate risk allocation and risk-sharing". Therefore, it can be concluded that there are certain common critical success factors for conducting PPP projects, irrespective of the geographical locations. Meanwhile, Hwang et al. (2013) identified the critical risk factors and preferred risk allocations for PPP projects in Singapore. This indicated that negative factors were more affirmative than positive factors and that 23 risk factors had significant criticalities. Eight risks would be preferably allocated to the public sector while 19 risks could be assigned to the private sector. 11 risks were preferred to be shared by both parties and the allocation of four risks depended on project circumstances.

The study from Tiong et al. (1992) indicated the importance and characteristics of CSFs that are vital for project sponsors in their endeavors to win lucrative BOT contracts. These factors are entrepreneurship, picking the right project, a strong team of stakeholders, an imaginative technical solution, a competitive financial proposal, and the inclusion of special features in the bid. However, 46 CSFs were identified, analyzed, and categorized into five main CSFs by Zhang (2005), including (1) favorable investment environment, (2) economic viability, (3) reliable concessionaire consortium with strong technical strength, (4) sound financial package, and (5) appropriate risk allocation via reliable contractual arrangements. Based on comprehensive review, Osei-Kyei and Chan (2015) found that several factors account for successful PPP projects however the top most five factors are appropriate risk allocation and sharing, strong private consortium, political support, community/public support and transparent procurement.

3.6.2. Research on risks of PPP for infrastructure projects

Risk research can help to explore the appropriate ways to manage the significant risks associated with PPPs for infrastructure projects (Tang et al., 2010). Hence, this domain has been attracted many studies to date (Abednego & Ogunlana, 2006; Alonso-Conde et al., 2007; C. Ameyaw et al., 2015; E. E. Ameyaw & Chan, 2015; Boeing Singh & Kalidindi, 2006; Chang & Ko, 2017; Effah Ameyaw & Chan, 2013; Grimsey & Lewis, 2002; Ibrahim et al., 2006; Iyer

& Sagheer, 2012; Pellegrino et al., 2013; Shen & Wu, 2005; Thomas et al., 2006; Trangkanont & Charoenngam, 2014; Xu et al., 2010; Zayed & Chang, 2002). Risks in PPPs may be grouped according to the conventional risk management process: identification of risk areas, risk analysis and risk strategies.

A risk probability and impact assessment framework based on fuzzy-fault tree and the Delphi method is proposed by Thomas et al. (2006). The framework includes extensive scenario modeling of critical risks in projects and the systematic processing of professional judgment by experts and is developed and demonstrated in the context of critical risks in Indian BOT road projects. Another more recent technique is a fuzzy synthetic assessment approach, which is becoming increasingly popular as a means of assessing the level of risk (C. Ameyaw et al., 2015; Xu et al., 2010). Grimsey and Lewis (2002) analyzed principles involved, drawing on the practical experience of evaluating infrastructure projects to present a framework for assessing the risks, and using as illustration a case study of a waste water treatment facility in Scotland which is typical of most PPP projects. The key risks common to many PPP projects that have an impact on revenue are traffic revenue risk, operating risk, demand risk, and debt servicing risk (Boeing Singh & Kalidindi, 2006), while the impacting costs include overruns of financing, construction and operating costs (Ibrahim et al., 2006).

As far as risk assessment methods are concerned, the most widely used technique is the application of a risk register matrix, which includes the specific impact and probability of occurrence of each identified risk. This can be considered alongside a two-dimensional value curve including performance versus value (Zayed & Chang, 2002). Strategies adopted by project managers generally depend on the predictability of the risk impact and the controllability of the risk outcome (Trangkanont & Charoenngam, 2014). Based on the identification and allocation of the main risks embedded in the project during the initial phase of the project (planning and design), decision-makers can easily find a cost-effective way to control risk and maximize investment value in an optimal way (Pellegrino et al., 2013). In addition, the Monte Carlo method is used as an effective tool for simulating indeterminacy during construction and concession periods (Alonso-Conde et al., 2007; Chang & Ko, 2017; Wibowo & Alfen, 2013).

3.6.3. Research on financing of PPP for infrastructure projects

Financing plays a key role in the PPP projects. Research focusing on model development addressed different financing issues (Cheung et al., 2012; Hwang et al., 2013; Jefferies, 2006; Yongjian Ke et al., 2010; Li et al., 2005; Junying Liu et al., 2015; Olusola Babatunde et al., 2012; Tiong et al., 1992; Zhang, 2005). Since 2000, related articles have paid more attention to the detailed issues in the financial package (Cui et al., 2018). Many studies have been tried to research the financial viability of PPP infrastructure projects (Akintoye et al., 2003; Fantozzi et al., 2014; Grimsey & Lewis, 2004, 2005; Ho & Liu, 2002; Iyer & Sagheer, 2012; Schaufelberger & Wipadapisut, 2003; Smith et al., 2004). For instance, Ho and Liu (2002) used an option-based pricing model to assess the financial viability of a privatized infrastructure project. In order to estimate when the project is at risk of bankruptcy, this quantitative model takes into account the views of the project promoter and the government. The literature was reviewed and qualitative analysis was used to examine factors that could continue to challenge the achievement of best value was undertaken by Akintoye et al. (2003). They found that, among other things, the high cost of the PFI procurement process is a key factor, which is a burden on the PPP project, leading to a reduction in the willingness of the private sector to participate.

The study of Smith et al. (2004) analyzed the negotiation, construction and operation phases of the Huaibei Power Plant Project in China and found that the development of PPP markets depends on whether the PPP payment mechanism can be properly managed as an incentive. Schaufelberger & Wipadapisut (2003) explained that the availability of funding significantly influenced the selection of a favorable financing strategy. Such a strategy can support the participation of the private sector.

3.6.4. Research on relationship among parties of PPP for infrastructure projects

Relationships between public and private sector organizations are seen as crucial to the success of PPPs in infrastructure projects, because poor relations would easily lead to misunderstandings and conflict (Tang et al., 2010). In some projects, there is a discrepancy between the complicated governance approach and the relatively straightforward infrastructures that have been developed, which has led to the argument that a better sense of contingency is needed in future PPP programs (van den Hurk & Verhoest, 2015). Therefore, many researchers have examined what factors facilitate or inhibit the relationship between PPP infrastructure project's parties (Abdul-Aziz, 2001; Chan et al., 2003; Consoli, 2006; Erridge & Greer, 2002; E. Palaneeswaran & Kumaraswamy, 2000; Ekambaram Palaneeswaran & Kumaraswamy, 2000; Smyth & Edkins, 2007; van den Hurk & Verhoest, 2015; Ysa, 2007; Zhang, 2004b, 2004a).

The study of Chan et al (2003) found that "improved relationship between project participants" and "improved communication between project participants" were the most significant benefits from the use of partnering in PPP projects. Abdul-Aziz (2001) argued that, once privatization has taken place, the re-involvement of the public sector, in particular through the injection of new funds, should be avoided as much as possible due to the lack of expert experience and the potential social impact of the project. However, Consoli (2006) found that different stakeholder demands, contractual arrangements and philosophic points of view created friction between the parties involved. Apparently, friction is the main course of poor relations. Researchers also related the issue of the contractor selection relationship. In selecting suitable contractors, researchers have not only suggested benchmarking of 'best' selection practices, but have also emphasized "innovative" approaches to selecting contractors to be used by large public clients, in which the relationship is always seen as a key criterion (E. Palaneeswaran & Kumaraswamy, 2000; Ekambaram Palaneeswaran & Kumaraswamy, 2000; Zhang, 2004a, 2004b).

4.   FUTURE STUDY SUGGESTIONS

The existing body of literature on PPP for infrastructure studies has allowed for advancements in PPP infrastructure projects practice. Nonetheless, there are some flaws and challenges in PPP theory and practice when it comes to infrastructure projects. The review of the PPP for infrastructure studies provided insights into the design of future research agendas. The following discussion, therefore, recommends a number of possible further research in this domain.

4.1. Social and Environmental Impact Assessment for PPP Models Development

The impact level of the social and environmental issues should be established, particularly when relating to different PPP types, for PPP projects to run smoothly. PPP decision models can be developed using both empirical and operational studies. Conceptual models can be established empirically based on case studies and validated with a representative sample. Furthermore, a suitable decision-making methodology should be used to set up a decision

model for estimating the specific impact level of social and environmental problems on a specific PPP infrastructure project.

4.2. Performance Evaluation Criteria for PPP Projects Long-term Viability

There are still no structured, systemic, or operational mechanisms in place to assess whether PPP outputs are sustainable over a long-term contractual period (Junxiao Liu et al., 2016). Improving the sustainability efficiency of PPP infrastructure projects should be a top priority. Hence, it should be encouraged academic researchers have focused on enhancing economic, social, and environmental performance standards in assessing project viability through sustainability performance assessment of infrastructure PPP projects. Furthermore, parties of PPP infrastructure projects should launch a comprehensive and long-term marketing strategy to ensure that the public can be innovative in developing financial packages and allocating resources to boost PPP efficiency and maintain a competitive edge.

4.3. Development of Flexible Contractual Agreements

When it comes to dealing with ambiguity, flexible contracts are more fitting, and they are a sensible solution for PPP ventures. Despite the fact that the terms "flexible contract" and "renegotiation" introduce different alternative methodologies or rules, they are still in their infancy and have a lot of space for development. Since negative behavioral traits may contribute to adversarial or litigious relationships during contract execution, further research is required to evaluate which factors influence conduct. Hence, researchers can incorporate strengths from current methodologies to analyze contract flexibility classification and calculation, as well as flexible contract terms, complex contract supervision, and renegotiation triggers, among other topics.

5.   CONCLUSIONS AND LIMITATIONS

This study provided a thorough analysis of the status quo, gaps, and research suggestions for the future of PPP research for infrastructure projects, in response to the increasing interest in the research and application of PPP procurement. This paper performed a scientometric analysis based on the literature data of 1749 publications on this domain from the collected Scopus core set for the period 2000-2020. The VOSviewer software was used in this study to identify emerging research-front terms and concepts, as well as pivotal points with high betweenness centralities in research networks in this field.

This paper found that there was a significant increase in the number of publications on PPP for infrastructure since 208. Researchers from the USA, China, and Australia have been the main contributors to this research area through regional analysis. Among the research journals in the field of PPP for infrastructure, the Journal of Construction Engineering and Management is the most published journal in the period from 2000 to 2020, followed by the International Journal of Project Management and Sustainability (Switzerland). The results of co-occurrence analysis of keywords show that public-private partnerships, infrastructure, PPP, and public-private partnership are nodes with both high citation frequency and high centrality.

In addition, four main themes of research on PPP for infrastructure are explored, including research on success factors of PPP for infrastructure projects, research on risks of PPP for infrastructure projects, research on financing of PPP for infrastructure projects and research on relationship among parties of PPP for infrastructure projects. Several research gaps and research directions in this area are established as a result of this. The results can be used to draw some

conclusions about the current state of PPP for infrastructure research and to help researchers choose potential research topics.

The parameters used in selecting the papers for the analysis are the study's limitations. The study's dataset retrieved from the Scopus search engine and may have been holes in coverage. Since this research was limited, similar studies could be conducted using data from more libraries or search engines, as well as taking into account books and other sources.

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PERI-URBAN AND INFORMALITY IN TELUKNAGA, TANGERANG REGENCY, INDONESIA

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ABSTRACT

'Desakota' has been acknowledged as a unique landscape condition in South East Asia and Indonesia especially. In the middle of emerging economies and rapid urban development, 'desakota' as a peri-urban area suffers environmental degradation in the economy and socio-culture because of poor planning and control from state and local authority. Inequality, spatial segregation, and inadequate infrastructure or slums are issues that peri-urban'desakota' has to encounter. Nevertheless, as a tool for producing and adapting the built environment and introducing a spatial order, urban design shows less concern for developing this distinct peri-urban area. This study conducted in Teluknaga, Tangerang, the neighboring Jakarta, examined the significance of informality which shapes a compact urban form in the 'desakota' area. Data collection of the study was done through field study by conducting interviews, observations, and direct mapping. We conclude that the informality potents should be considered for designing 'desakota' to maintain its compact form and create a more sustainable urban form and a better urban life.

Keywords: Compact city; desakota; informality; kampong; peri-urban

1. INTRODUCTION

The term peri-urbanization refers to the formation of mixed spaces and also a process in which rural areas located on the outskirts of established cities transition are becoming more urban, physically as well as economically, and socially (Dupont, 2005; Webster, 2002). This peri-urban development process has begun since the Industrial Revolution and transformed into an escape for many people from the chaotic situation in the city center (Gallion & Eisner, 1963). However, each country's peri-urbanization is highly contrasted between cities in developed and developing countries (Woltjer, 2014). In terms of spatial manifestation, peri-urbanization in the north is driven by suburban development called urban sprawl; meanwhile, in the south is known as 'desakota' (McGee, 1989), of which one of the characteristics is the urban-rural interplay. As a distinct landscape condition, 'desakota' still needs more concern from the urban design field's perspective.

Peri-urban areas in East Asia, which also refers to 'desakota,' particularly in Indonesia, suffer from problems such as uncontrolled and conflicting land uses conversion, spatial equity, or segregation, and inadequate infrastructure (Legates & Hudalah, 2014). Despite the problems, the desakota also has some advantages, according to some studies. McGee, who consistently studies about 'desakota' had remarked some findings. Firstly, transition theory in cities in western countries is flawed.

Secondly, the coexistence of agriculture, industry, and other urban activities in the form of a mixed-use landscape offers the most viable option for preserving eco-systems within the EMR and producing a liveable and sustainable city region. East Asian countries should be developing their response to the rural-urban transformation (McGee, 2008). Aligns to McGee's study, Cairns argues that Asia's urban-rural regions may not necessarily suffer the same fate as European and North American cities enduring from urban sprawl patterns. Both McGee and Cairns agreed that this potential of 'desakota' requires new distinct approaches to urban planning and design.

It is estimated that the population of peri-urban areas in East Asia will increase by approximately 200 million people over the next twenty-five years, accounting for 40 percent of urban population growth in that region (Webster, 2002). According to Legates and Hudalah (2014), the peri-urban areas of developing East Asia are the epicenter of world urbanization. This epicenter contains a mix of formal estates and informal settlements, which refers to "kampung" or slums in Indonesia (McConville & Wittgren, 2014). As Kusno argues that Kampung (in the city center or the case of this study "desakota" region) is a mediation place (placed in the middle) between city and village for immigrants from the village by offering an affordable life, so it is called 'Middling Urbanism' (Kusno, 2020b). Kampung cannot be separated from the formal city but has a strong relationship between space, economy and capital, and politics. The existence of the village is essential. Therefore, study about peri-urban 'desakota' is highly needed, aside from problems and the potentials that 'desakota' has.

Peri-urbanization faces the informality challenge as the industrial cluster development and other non-agricultural sectors are keep growing (Irawati et al., 2016). On the one hand, the growth of the informal sector also fulfilled the need of the people within the framework of Urban DMA (Dovey, 2016). In the typical fast-growing Indonesian cities of Depok, the informal development in Kelapa Dua district caused several urban spatial problems and degradations (Wasnadi & Ellisa, 2019). We hypothesize that kampung as the informal settlement with the informal economic activities is a significant aspect to be considered for the development of the peri-urban area. Cozzolino et al. (2020) reviewed informality as identical to self-organization that should be intended as complementary rather than contradictory elements. The spontaneous spatial configurations may continuously emerge within intentionally created design frameworks. While, both McGee and Cairns had emphasized more on mixed land use and the potential of food production that peri-urban areas possess, the informality which becomes daily facts and natural challenge for the peri-urban condition is less concerned. Therefore, this study aims to examine the significance of informality in the 'desakota' area regarding how it affects the urban form and future development.

The study is conducted in a district located in the area adjacent to the megapolitan Jabodetabek, namely Tangerang Regency. Tangerang Regency is a district located on the west and north side of Kota Tangerang and DKI Jakarta. With an area of 959.60 km2, Tangerang district has 29 districts. Like most districts, the area of the Tangerang Regency is reasonably large. As a result, some districts (*kecamatan*) are located very far from the center of their Tangerang regency (*kabupaten*) which is the center of activity for administration and economic activities. As the center, Tangerang city receives more attention for development. In most sub-districts, land use is dominated by green land uses, particularly agriculture. On the south side, several Tangerang district parts are the new towns rapidly developed by major developers in Indonesia, namely Lippo Karawaci and BSD City. In addition, the development of industrial estates with various scales that are not well controlled and planned is also spread in almost all parts of the Tangerang Regency. This development results in the "desakota" patterns characterized by a mix of agricultural, residential, industrial, and commercial areas.

2.   LITERATURE REVIEW

2.1. Peri-urbanisation and Urban Design

The word peri-urban describes the interface between rural and urban activities and embodies a transition from rural to urban norms, legislation, and institutional settings, in which social structures, commercial activities, and even the built environment are in flux (McConville & Wittgren, 2014). McConville's definition of peri-urban about transition and physical changes aligns with Dupont's (2005). 'Peri urban' is an area outside existing urban agglomeration where large changes occur over space and time (Dupont, 2005). This transformation and change of peri-urban began from the industrial revolution era due to the congestion in the city center. Later, some scholars regard this transformation of peri-urban as "peri-urbanization" (Dupont, 2005; Webster, 2002). The term peri-urbanization refers to the formation of mixed spaces and a process in which rural areas located on the outskirts of established cities transition more urban in physical, economic, and social (Dupont, 2005; Webster, 2002). Peri-urbanization, which occurs in suburban development, led to urban sprawl patterns like in European and North American cities.
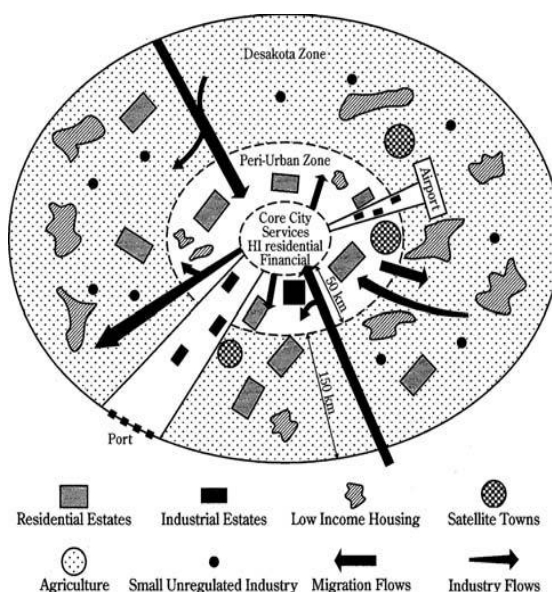
Figure 1 Configuration of mega-urban in Asia
Source**:** (McGee, 2008)

On the other hand, the phenomenon of the global south peri-urban occurs differently. The transformation phenomenon is known as 'desakota,' introduced by Terry McGee (1989). This phenomenon is caused by the fragmented growth of the industrial sector in the city's outskirts, which is still rural. Spatially, this transformation results in mixed of land use, between agriculture and industry. Besides, the socio-economic impact that occurs is a shift in the economic sector from agriculture to industry, trade, and services and an increase in the participation of women as workers (McGee, 1989). McGee (2008) also identified the type of spatial configuration in big cities (mega-urban) in Asia (see Figure 1). With these different patterns of transformation, discourses regarding peri-urban development in Asia have begun to emerge. As he continued his study of "desakota" in East Asia, McGee argues that the concepts of urban transition and transformation are not the same in each city. The urban-rural in East Asia must go through the transitions that European and North American cities do to develop.

To manage the spatial transformation of "desakota," urban design and designer are required to come into play. Urban design plays a role in addressing the uncontrolled and fragmented land-use development as one of the main features of urban design by introducing a spatial order

based on a certain principle (Cozzolino et al., 2020). Some studies from urban design fields have been conducted which proposed a spatial order. Some of these studies will be discussed in the following paragraph.

According to Cairns et al. (2017), urban-rural area (peri-urban 'desakota') is a pathway to a distinctive, sustainable urban development by integrating high dense populations, diverse land uses, robust economies, rich natural ecologies, and vital sites of food production. Aligns with McGee (2008) about urban-rural transition, Cairns argues that urban-rural regions in Asia's urban-rural regions may not necessarily suffer the same fate as the urban sprawl in Europe and North American cities. He stated that it threatens cities' functional diversity, environmental sustainability, and, by encroaching on fertile agricultural land, it is a resilient approach to food production. Specifically Indonesia, he argues that Indonesia currently experiences an increasing agricultural land conversion due to a lack of control and inability to successfully enforce the land development and spatial planning policies and regulations from the local government (Stephen Cairns et al., 2017).

Cairns proposes an idea about developing an urban-rural area in Indonesia. The idea is called 'tropical town' (Urban-Rural Systems, n.d.). A 'tropical town' is a design area in the form of a small town with local food production and other facilities that support the self-sufficient city. He has started this idea by building a prototype of "Expandable House" in Batam, Kepulauan Riau, Indonesia. This idea responds to a unique urban-rural condition of Indonesia and rooted in the incrementality of the Indonesian houses' vernacular architecture.

A Singaporeans architect, Tay Kheng Soon, also offers opinions and ideas regarding the peri-urban development model. He is explicitly stated in his proposition "Rubanisation" (Tay, 2013)that the "desakota" phenomenon by McGee (1989) is nothing but the failure of a regional development model. As a critic of urban and rural dichotomy and capitalistic of a city system, he proposed an idea named 'Rubanisation.' "Rubanisation" is a fusion between rural and urban form, which McGee also means about the idea of managing rural-urban in East Asia. The idea of "rubanization" also aligns with the previous idea, namely Agricultural City by Kurokawa (1977). Kurokawa proposed an idea named Agricultural City, which is a combination between a city (with its urban characteristic) and a village (with its rural characteristic). A village could also be a city, or in other words, urban and rural are blended in one region.

As a conclusion of this review, we know that urban design as an organizer of spatial order needs to address the "desakota" issues. Thus, those mentioned studies also show the urgency of the urban design field to observe it further. The urgent study regards the statement of McGee (2008) and Cairns (2017) about the need for a distinct planning and design approach, aims to find an appropriate approach to address the issue of spatial order and production and adaptation of the built environment of the desakota region.

2.2. The informality of Peri-urbanisation and Urban Design

Urban informality can emerge in two forms: informal practice (hawkers, illegal parking, etc.) and informal settlement (Dovey, 2012). There are three informal settlement typologies based on the processes of informal settlement growth, such as settling, inserting, and attaching (Dovey & King, 2011). Settling is an unclaimed and often unbounded land as indigenous villages and towns have come about over millennia. Inserting is a process of inserting into the uninhabited, abandoned, or leftover fragments of urban space. Lastly, attaching is informal accretions or excrescences grow out of, or attach onto, the structures of the formal city.

Nevertheless, the three types potent to emerge in various cities. As far as the informal typologies are concerned, informal settlement growth processes are always related to the formal

city. The peri-urban area contains a diverse mix of informal and formal settlements or planned and unplanned settlements (McConville & Wittgren, 2014). Thus, based on this classification, the informal settlement in the "desakota" region emerge in settling type.

Urban informality is also recognized by the term "urban messiness" (Chalana & Hou, 2016). "Messiness" denotes urban conditions and processes that do not follow institutionalized or culturally prescribed notions of order. It suggests an alternative structure and hierarchy and agency and actions that are often subjugated by the dominant hierarchy, including notions of spatial and visual orders as well as social and political institutions and cultural norms. Amid the development of discourse in urban planning, such as the Garden City movement (Ebenezer Howard), the City Beautiful movement, and the Modernism movement (such as Le Corbusier), informality is considered a city disease. Hence, it is something that must be eliminated (Chalana & Hou, 2016). Urban informality is defined as a city condition lacking formal control, planning, and construction, but it does not necessarily mean a slum area or a squatter (Dovey & King, 2011). Kusno (2016) also argues that informality, if it is viewed from the vision of an order, is a condition that is uncontrollable, irregular, even anarchist, which can be overcome by modernization.

Another study asserts that informality or "kampung" (not only in the inner city but also in the outskirt of the city) and formal city form a reciprocal relationship yet not equal (Kusno, 2020b). The author relates the position of the "kampung" to capital, which supplies laborers to the formal business and capitalist economy. In his public lecture, he extended his opinion whether "kampung Kota" and also "desakota" is a transitional space or an exceptional space that is suppositionally changed into permanent (Kusno, 2020a).

Informality and peri-urban condition somehow has a similar description. For instance, informality implies a lack of formal control over planning, design, and construction (Dovey, 2012). Meanwhile, peri-urbanization also describes a mixture of planned and unplanned settlements, inadequate service infrastructures, insecure land tenure, social tension, and environmental and health problems (Legates & Hudalah, 2014; McConville & Wittgren, 2014). Therefore, it can be said that informality is the nature or peri-urban or "desakota" region. Thus, this study considers "kampung" in the "desakota" region as an exceptional and permanent space as observed from the role and multidimensional interconnection within the city.

3. RESEARCH METHODS

Our study aimed to reveal the question of whether the "desakota" area potents to perform the characteristics and requirements of a compact city. To answer the research question, we tried to undertake the field survey to understand how the residents of informal settlements adopted the informal daily practice in conjunction with the formal development of the public places and facilities. We try to analyze the possibility of Teluknaga becoming a compact city based on three core aspects in defining the compact city's idea: 1) density, 2) mix used, and 3) accessibility.

This research was conducted using a combination of observational surveys and in-depth interviews. Guiding by the google-map, we conducted the initial survey by slowly walking down the areas of Teluk Naga district to confirm the situation depicted on the maps and experiencing the spaces before mapping all attributes and situations indicated the density, the building functions, and the accessibility. We conducted in-depth interviews with 10 (tens) respondents of residents who lived in the kampung near the district center with different backgrounds (and mixed-income). The residents who have been long enough in the kampung were deliberately chosen as respondents for their ability to understand their habitation. For

example, to understand the land ownership of informal settlements, we asked their dwelling histories through asking how they occupied the land, built and resided in their shelters. To understand how they dealing with the scarcity of resources, we asked how they get electricity, drink water, and other needs in everyday life. We also asked their experience of mobility through asking whether they do travel to the center city of Tangerang (which is 12 Kilometers away from Teluk Naga) or not and why. To understand their connection to the district center of the peri-urban area, we asked their view and perception of Teluk Naga center in relation to their daily needs and expectation.

Mapping is conducted by combining direct mapping and google maps. The mappings are land use, formal and informal public transportation line and spot, and identification of ongoing and future development of the surrounding area. We referred to Kim Dovey: "The aim is not to produce a facsimile of the city nor an image to be replicated but to spatially expose the abstract set of forces that produces and sustains the city for better or worse. These forces may be political, material, aesthetic, social, economic, or environmental" (Dovey & Ristic, 2017).

4.   RESULT AND DISCUSSION

4.1. Peri-urbanisation in Teluknaga, Tangerang Regency

One of the sub-districts in the Tangerang Regency, which is become our case study, is Teluknaga. Geographically, Teluknaga is located on the northern coast of Tangerang. Teluknaga is district (*kecamatan*) with some sub-districts (*kelurahan*). It has 40.58 km2 with a population density of 3300 people/km2 and consists of 13 sub-districts (*kelurahan* and *desa*). Geographically, Teluknaga District is far from the center of the Tangerang Regency government. However, Teluknaga District is closer to Kota Tangerang and DKI Jakarta. The area is also adjacent to the International airport of Soekarno Hatta.

Figure 2 Map of study location
Source: Survey by the author using the map adopted from google map

According to BPS data for 2019, four urban villages are holding the status of the urban category, namely Kampung Melayu Barat and Timur, Pangkalan, and Kampung Besar, while the rest are still in the rural category. Two of the four *kelurahan* have the highest population density in Teluknaga District. More specifically, the location of this study is the center of the sub-district of kelurahan Kampung Melayu Barat and Timur, where the square, sub-district office, police station, health center, and the subdistrict's grand mosque are located.

Figure 3 View of agricultural land in desakota region of Teluknaga
Source: Google Street Map

Analysis through mapping revealed that the existing conditions around the central area of the Teluknaga sub-district are undergoing some significant developments. On the west and east sides of the four "kelurahan" that are the industrial areas are developing rapidly. The transformation could be seen in the map over the last 15 years, where significant growth can only be visible in the industrial sector. Meanwhile, on the north side of the sub-district center, there have been extensive housing and urban infrastructures, such as the development of Pantai Indah Kapuk 2 and the JORR 2 toll road.
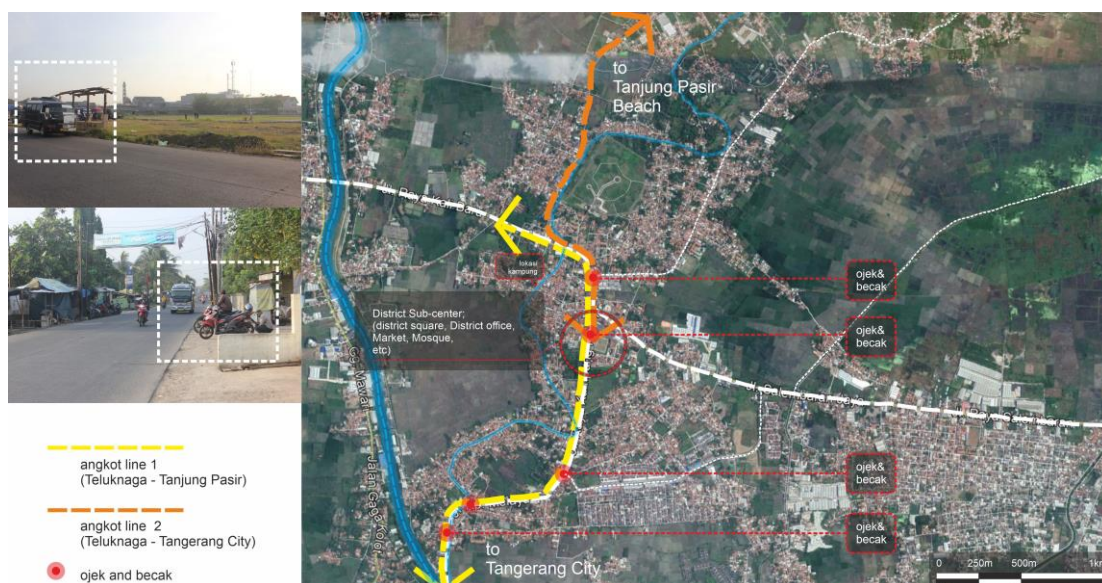

Figure 4 Accessibility in Teluknaga
Source: Survey by the author using the map adopted form google map

In terms of accessibility, this district sub-center area only has two types of formal public transportation. First, public transportation to and from Tangerang City of large "angkot"

(private paratransit minibus), headquartered in groups depending on the owner, for example, in the market parking lot, the square, or the front of a group of private houses. Second, public transportation of regular/small/white "angkot" heading to and from the Tanjung Pasir coastal area. Apart from these formal public transportations, there are informal and traditional public transportation, namely motorcycle taxis (*gojek*) and rickshaws (*becak*). Motorcycle taxis and rickshaws are scattered at several busy intersection points. The intersection point usually connects the main road (Jalan Raya Kampung Melayu) with small roads leading to residential areas.

4.2. Land use and Informality Analysis

The central area of the Teluknaga sub-district is relatively busy. Various building facilities and functions are scattered along the main road of Jalan Raya Kampung Melayu. Overall, all functions for the domestic requirements and daily activities of the residents have been fulfilled. Within the radius of 500 meters from the sub-district, there are main functions such as traditional markets, clinics (*puskesmas*), education facilities (SD of primary school, SMP or elementary school, and SMA or high school), and religious buildings (mosques, churches, and monasteries). Within a radius of one kilometer, located health facilities and city-level recreational services such as major hospitals and sports fields (football, futsal, etc.).

There is a public square in the center of this sub-district, facilitated with an open field, a running track, and a parking lot. However, this square is still relatively new, officially utilized by locals' residents in 2019, but in a condition that does not seem to be finished. This contemporary square was built following the relocation of the sub-district office (*kantor kelurahan*) at the (east) side of the square. Prior converted into the square, it was a poorly defined field known as the Tunas Jaya field. It was not fully open to the public since it was mainly utilized for formal ceremonies and education activities such as ceremonies, speech, student sports, camp, school performance, and other school activities.

The re-arrangement of the kelurahan office building complex affected the way the people utilize the new square. While the previous office arrangement and open space were rather conventional and poorly designed, the new composition of buildings and squares accommodated a more modern outlook. The new square represented the image of a typical plaza in other cities in Indonesia. In this square, both the activities and users are very diverse. This square is quite busy during the day and night. Residents enjoy various activities, ranging from women practice jogging and gymnastics, people of all ages relaxing/hanging out teenagers playing skateboarding, and other leisure activities. The activities and crowd of people trigger informal activities such as "angkot" parking and street vendors. The previous empty field with hardly any essential activities has been transformed into the square that has become one of the recreational destinations for Teluknaga residents. The square provides the residents a place for gathering and gives them a sense of belonging.

Another major feature in the Teluknaga area is the dense informal "kampung," as housing in the Teluknaga area is predominantly "kampung." According to the local people, Kampung at Teluknaga has been inhabited by at least three generations. However, as most of the inhabitants of the "kampung" in Teluknaga do not have strong land ownership, it is classified as an informal settlement. Some houses are semi-permanent buildings made from wooden structures. The kampung at Teluknaga has been grown organically without proper infrastructure. Administratively, several houses share one source for electrical supply, of which each house will pay the bill based on its electrical usage. A Group of tiny houses usually attached to a house that is bigger or more prosperous economically. Some households carry out ritual

cleaning activities such as bathing, washing, and defecating communally in modest MCK (communal bath and toilet) located in the river.
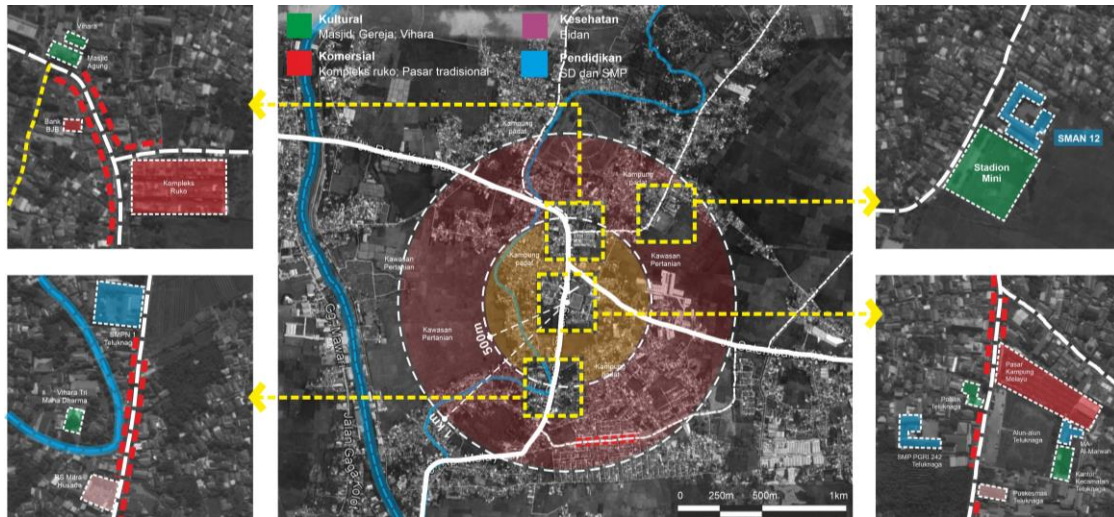
Figure 5 Land use analysis in 500m and 1km radius
Source: Survey by the author using the map adopted from google map

Based on the daily observations and semi-structured interviews with several residents, it is revealed that most of the residents of this kampung are the low-income group. Predominantly they are involved in the informal sector, such as hawkers, day laborers, or are employed in the local private or public sector. When we were asking about the place they have been traveled to so far, they said that they never been to the city center of Tangerang. It means that almost the whole time in their lives, they have never been traveled outside Teluknaga sub-district, even though Tangerang city is only 12 kilometers away from their homes because there is no necessity to do so. This "living locally" which is performed by kampung residents correlates with the spatial mapping that shows all the daily needs are met in 10-15 minutes of walking or cycling. It also corresponds with the residents' responses that they have no reason to travel to Tangerang inner city.
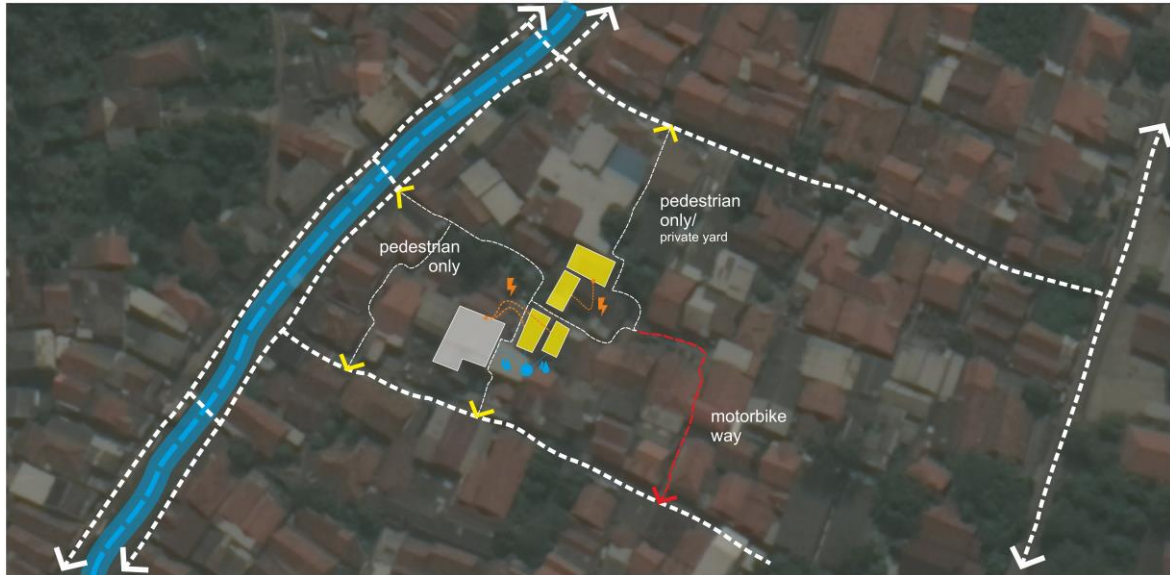
Figure 6 The condition of "kampung" in Teluknaga
Source: Survey by the author using the map adopted from google map

4.3. Informality, Peri-urbanisation, and Compact City

Hayashi (2003) states on the idea of 'compact city' as a form of urban regeneration. In his review, this idea was born against the background of shrinking cities' symptoms (decreasing population) experienced by cities in developed countries, including Japan. With the shift of industrial activity from the city center to the city's outskirts and the results of de-urbanization and suburbanization, the city center has become deserted due to the abandonment of its inhabitants. The key to the concept of a compact city is the intensification or concentration of density. Hayashi (2003) illustrated the compact city effect can reduce vehicle use (41%) and air pollution (38%) (the context of his study in Nagoya, Japan). The concept of a compact city indirectly makes humans an important aspect of a city, unlike industrial cities and the urban expansion that is car-oriented and industrialist or commercialist (Tay, 2013).

Dovey's intensification focuses on the concept of Urban DMA (Dovey, 2016), namely density, mix, and access. This concept is rooted in Jacobs' (1961) theory of diversity but further developed. Density is a consideration of the closeness between people and their destination. The mixture is not only on functions, people, and activities; but also on living, working, and playing, even production, consumption, and transactions. Access is how places are connected through a road network or transportation (walking, cycling, or motorized vehicles). This DMA concept will then form an urban intensity to achieve a compact city and a high walkability city (allowing people to walk).

Figure 7 The diagram of the DMA concept by Kim Dovey
Source: (Dovey, 2016)

Carlos Moreno, professor at the University of Paris 1 Pantheon-Sorbonne, proposed a concept of '15 minutes city' for Paris, France. It is a city where residents can reach all their daily needs (home, work, school, and other facilities) in just 15 minutes of cycling. Again, inspiration comes from Jane Jacobs's theory of proximity, which is the key in shaping the vitality of a city. He stated that the concept of a city with the mobility of commuters from the suburbs was outdated. The goal is not only in response to climate change and pollution from vehicles but also about improving human life quality (Peters, 2020). This idea has also been applied in other cities such as Melbourne, Ottawa, and Detroit (Reimer, 2020). This concept is nothing more than an implementation of the compact city principle. Compact city has dramatically influenced the planning of cities in the world.

Bibri et al. (2020) collected literature that discusses the sustainability benefits of a "compact city." There are three aspects of the benefits of a compact city, such as environmental, economic, and social. Each aspect has several points of benefit; for instance, on environmental aspects, the compact city can reduce the carbon footprint of the use of vehicles and energy, conservation of green space, and others. In the economic aspect, it can support local micro-businesses by increasing density, proximity, and fostering livelihoods for its residents. In the social aspect, it can improve the quality of social life of its inhabitants through social interaction, and access to green open spaces (Bibri et al., 2020).

The observation of the daily activities and the investigation on the spatial arrangement and spatial usage in this case study had revealed that Teluknaga districts sub-center fulfill the characteristics and requirements of a compact city form. Although most of the residents lived in the typical kampung and adopted an informal daily life practice, their living environment met the three aspects pre-requested of the idea of a compact city; density, mix, and access. Teluknaga sub-district demonstrated the potential and the possibility to develop as a compact city in 15 minutes.

5.   CONCLUSION

Located in the peri-urban area of greater Jakarta, Teluknaga is still dominated by informal settlements. Although the formal, modern, and city-scale urban facilities rapidly developed in just a stone's throw away from Teluknaga, life in this sub-district is far from the hustle and bustle of the Jakarta megacity. However, at present, the improvement of public facilities and the infiltration of urban public life gradually shape a compact city form. Unlike the surrounding adjacent area, it is pervasive to see the local people of the Teluknaga area walk, cycle, and use traditional transportation such as *becak*s. Local people can *also* easily meet their daily needs such as food and entertainment, while productive activities such as work, schools, visit health services, and other essential activities are easily reached. However, unlike the compact city's idea in developed countries, informality becomes an additional element in forming a compact city. We assumed that Teluknaga reveals the new additional characteristic in defining the concept 'desakota' initiated by Terry Mc Gee.

This study contributes to the preliminary findings on the dialectical relationship between informality and the physical environment that is still a largely neglected issue in peri-urban studies. By focusing on informality, we need to consider the potential to focus on the rationality of everyday life rather than a grand scale of a dramatic transformation of peri-urban. We suggested the need to maintain the existing character of the compact city form of Teluknaga and consider the role of informality that makes it work. In this case, we are agreed with Chalana and Hou (2016) that if you want to understand urban life as a whole, you must understand informal life, which is sometimes hidden, vague, or under-appreciated, which also occurs in it. We have to admit our limitation in this study to reveal the significance of informality in the formation

concept of a compact city in the 'desakota' area. Therefore, further studies are needed to find the spatial formation processes that emerge as the consequence of informal "kampung" activities and informal economic activities. Thus, informality should be considered as one of the important factors to define the 'desakota' area toward the sustainable city form and better future.

6. ACKNOWLEDGEMENT

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MAJOR BARRIERS ASSESSMENT OF LEAN CONSTRUCTION APPLICATION IN CONSTRUCTION PROJECTS DELIVERY

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ABSTRACT

The construction sector is facing challenges of meeting client's value and end-user satisfaction, and this situation is worsened by customers' dynamic demands for quality and speedy delivery without loss of value. Lean concept has been advocated to be a panacea to poor project performance, and it, however, has a high awareness level but with little implementation among construction organizations especially in developing countries including Nigeria. The purpose of this study is to assess the major barriers to lean construction application on construction project delivery, to suggest possible measures for overcoming them. A well-structured questionnaire was used to gather data from construction professionals in the south-south, Nigeria using electronic means and snowball sampling technique. Data gathered were analyzed using frequency, percentage and factor analysis. It was found that the major cluster of barriers to lean implementation are technology and knowledge barrier, leadership and management barrier, culture and complexity barrier, engagement and relationship barriers, financial barriers, and communication barriers. It was recommended that adequate management and leadership support is needed for entrenching lean construction techniques into the culture of operations of construction organisations.

Keywords: Lean construction; construction projects; barriers, lean techniques, Nigeria

1. INTRODUCTION

Evidence in literature has shown how critical the construction industry is on national economic growth and development. According to Nwaki and Eze (2020), the impacts of the construction industry are in the form of infrastructure and building housing provisions, wealth creation, generation of employment, and national income constructions. The construction industry is critical to economic growth of both developed and developing nation (J. G. Sarhan et al., 2017; Tezel et al., 2018). The sector is, however, facing challenges of meeting client's value and end-user satisfaction, as it is being limited in its contribution to sustainability issue (Babalola et al., 2018). The challenge is worsened by the increasing competitive pressure on construction enterprises; a resultant of customers' dynamic demands for quality and speedy delivery without loss of value (Yadav et al., 2018).

There are non-value-adding activities that characterized construction project delivery. These have culminated into problems such as overruns in time and cost, poor quality and materials waste, safety issues, efficiency problems, and insufficient clients' satisfaction (Sols, 2018). A suitable way for minimizing these problems and maximizing values while removing non-value-adding events during building production is by 'producing it lean'. The lean concept is common in the manufacturing sector, and a lot of success has been recorded. Li et al. (2019) posit that since there is a lot of similarity and commonality existing between construction and manufacturing, lean thinking was introduced to solve problems related to non-value-adding activities.

In spite of the enormous benefits such as cost and time savings, better safety performance records, reduction of errors and rework, improved quality and waste reduction, better predictability of work, improved productivity, enhanced inventory management, and improved client satisfaction (Farrar et al., 2004; Ko, 2010; Mohan & Iyer, 2005; Salem et al., 2006), recorded by leading economies in lean construction (LC) practices adoption, the concept is still at the development stage. Countries like the USA, Brazil, the UK, Chile, Denmark, South Korea, Peru, Ecuador, Finland, Venezuela, Australia, and Singapore; are the leading economics for LC adoption (Ballard & Howell, 2003; Johansen & Walter, 2007; Jørgensen & Emmitt, 2008). Lean construction is a novel approach and it is still growing rapidly in recent years (Monyane et al., 2020; Shang & Sui Pheng, 2014). This has contributed to the slow adoption and widespread interpretation and a missing rational philosophy (Alves et al., 2012; Common et al., 2000; Jørgensen & Emmitt, 2008). Albalkhy and Sweis (2020) posit that LC is either not adequately known or fully welcomed in many developed and developing economies.

In the extant literature, studies on the challenges and limiting factors to lean implementation in many countries still exist, particularly the low adoption level of lean in construction. (Ayalew et al., 2016; A. M. Bashir et al., 2015; Cano et al., 2015; Johansen & Walter, 2007; Olamilokun, 2015; S. Sarhan & Fox, 2013; Shang & Sui Pheng, 2014). There is, however, limited literature on the factors hindering LC practices implementation in the construction industry of Nigeria (Sholanke et al., 2019). Furthermore, in Nigeria, the lean concept is still not implemented on a full scale, and maximizing the full benefits of lean has remained a mirage. Construction organizations are reluctant to fully implement LC techniques which have proved to be an innovative solution to construction projects' performance problems (Nwaki & Eze, 2020). Srinivasan et al. (2020) suggested a study that will identify the factors affecting lean principles implementation on construction projects. It is based on this that this study assessed the major barriers to LC application on construction projects delivery, to suggest possible measures for overcoming them. Nwaki and Eze (2020) claimed that LC is a panacea for poor construction project performance; this is owing to its cost-related benefits, value and relationship benefits, environmental benefits, quality improvement benefits, motivation, and productivity benefits, profitability and market benefits, time and workflow benefits, waste reduction benefits, and HS and rework reduction benefits. It is only through a full-scale adoption of the lean concepts that these benefits can be achieved.

This study implies that it will increase the knowledge of construction-based experts on the critical barriers to lean concepts and enable them to develop sustainable strategies for overcoming them. This study further advance the knowledge of construction industry participants and serve as a caution for possible drawbacks when lean have gained complete acceptance and implementation in the country. The future driving forces for LC implementation are better organized from knowledge gained from a proper understanding of the key barriers to LC. It also adds to the existing literature on LC in developing countries of the world. The lean techniques eliminate wastes in the use of labor, time and ensure the efficiency of operations in

the use of materials for project delivery. Lean shortens the time of doing work, and efficient working saves money and energy on the project. LC application on construction projects means more money and less waste. Every stakeholder (clients, contractors, consultants, and others) are expected to feel the impact. Construction organizations would benefit from LC because it helps to reduced defects and errors, avoid over-production, eliminate waiting time, eliminate incorrect resource selection and poor use of knowledge, unnecessary transport waste, avoid excess inventory, avoid unnecessary motions, and avoid gold-plating of products. Less waste means that project could be delivered on budget and within an acceptable timeframe and meeting the functional requirements. Thus, delivering value to the client and securing their satisfaction.

2.   LITERATURE REVIEW

2.1. Lean Concept in Construction Industry

What is today known as LC and practiced in the construction industry, have its origin in the manufacturing sectors, especially from Toyota production system (Bajjou & Chafi, 2018; J. G. Sarhan et al., 2017). The eventual application of the lean philosophy in construction was premised on the successes the manufacturing sector recorded from the adoption of the lean principle and the benefits gained. Koskela (1992) was one of the pioneer authors who tried to introduce lean thinking in the construction industry. The applicability of what was called "the new production philosophy" is contained in the Stanford report produced by the author. According to Omotayo and Kulatunga (2014), after Toyota motors first introduced the lean concept to manufacturing, it has successfully been applied in the construction industry globally.

LC is a technique that focused on designing the production systems for material and time wastes minimization and value maximization (L Koskela et al., 2002). This definition of lean is the same as the main philosophy of lean in the manufacturing sector. Waste minimization and value maximization is the main philosophy of lean in the manufacturing. Scherrer-Rathje et al. (2009) state that the lean concept is a management philosophical tool aimed at reducing waste from the entire production value chain. Its application goes beyond production organizations but also along with supply chain networks. According to Hall (2019), LC is a philosophy adopted by construction organizations for a specific project being undertaken. The construction team applies lean practices and technologies to decrease time, costs, materials, and efforts, especially on a specific project at hand. According to Manrodt et al. (2008), LC adopts a systematic approach for enhancing value for clients by identifying and eliminating wastes through iteration of processes for continuous improvement in the pursuit of excellence.

Flowing from the aforementioned, LC is aimed at ensuring that the management of construction projects focuses on the minimization of waste and maximization of values for clients and project success.

2.2. Adoption of Lean Construction

In the Brazilian construction industry, Comelli et al. (2019) stated that adhesion to other process improvements by organizations made it difficult for LC to be implemented. Critical benefits assessment and evaluation of investment of lean is a vital and required exercise that must be done before LC principles are adopted (Campos et al., 2012). Furthermore, these efforts are needed for evaluating the investment and benefits that failed to be interpreted.

In Germany, Johansen and Walter (2007) reported that lean techniques awareness is low. Bashir et al. (2010) and Mossman (2009) in the UK observed that the implementation of lean construction practices is still limited. This situation according to Sarhan and Fox (2013) is attributed to cultural and structural barriers. Mahashabde (2016) reported that in the USA and India, the actual implementation of lean methods in construction projects has led to appreciable

successes in the reduction of waste and maximization of profit. Mahashabde (2016) further found that, although the lean implementation is high, the participants were not aware that they were using lean techniques to minimize waste and maximize profit.

In the Moroccan construction industry, Bajjou and Chafi (2018) found that the awareness of LC among construction experts is high but the adoption level is low. In the work of Wandahl (2014), it was found that 75% (i.e. 3 out of 4) of the practitioners are ignorant of LC practices. This poor awareness of the lean concept was attributed to the absence of knowledge, education, and communication issues. The level of awareness of the LC techniques is also found low among construction practitioners in Turkey and African countries (Ayalew et al., 2016; Tezel & Nielsen, 2013).

Babalola et al. (2018) found that although lean thinking awareness is growing, the adoption level remains comparatively low among construction companies. Similarly, Adegbembo et al. (2016) found that a larger proportion of the construction professionals are aware of LC techniques. 89% of the Architects sampled in the study are familiar with LC techniques (Sholanke et al., 2019). It can be deduced from the foregoing that while the awareness level of LC is high, its adoption and implementation level is low, especially in developing countries due to certain barriers that limit its implementation among construction professionals and organizations.

2.3. Barriers to Lean Construction

In a single case study survey in Norway, Lodgaard et al. (2016) found that the barriers to lean implementation based on the relative percentage weighting are limited management commitment, limited leadership, lean not a daily focus, roles and responsibilities not defined, lack of motivation, chosen tools, and practices not according to best practices, chosen lean tools and practices not adding sufficient value, and lack of knowledge about lean (philosophy, principles, tools). In a related case study research among Iranian SMEs, (Moradlou & Perera, 2017), through an interview, classified the main barriers to lean implementation into four groups; the absence of top management support, financial capability, absence of employee's skill and expertise, and organizational culture. Similarly, in the Iranian construction industry, Movaghar (2016) concluded that the most significant barriers hindering the implementation of LC in the developing countries are; lack of adequate lean awareness and understanding, culture and human attitudinal issues and, top management commitment.

In the UK, Bashir et al. (2010) carried out an in-depth analysis of barriers to LC implementation and categories the barriers into financial, educational, governmental, attitudinal, managerial, and technical barriers. In the UK, Sarhan and Fox (2013) reported that the cultural barrier is what characterized the LC implementation in the UK construction industry. Among these cultural barriers are the lack of adequate awareness and understanding, lack of management commitment, cultural and human attitudinal issues. Successful implementation of lean techniques depends on a strong lean culture supported by the management within the organization (S. Sarhan & Fox, 2013).

In the UK, the full-scale uptake of the lean concept appears to be sparse, and contracting organizations are faced with a lot of drawbacks in the implementation of lean practices. Bashir et al. (2015) found that the major factors responsible for the drawback in implementation of lean in the UK are; changing employees' working culture, cost of implementation, lack of lean knowledge, long implementation time, complexity, lack of cooperation from employees, lack of incentives, lack of long term forecast and investment, low effort to learn, misconceptions about lean, and high expectations from management. Further analysis of these barriers to determine the nature showed that they are more related to human and technical issues. It was suggested

that providing motivation such as staff training opportunities, provision of needed facilities, and incentives; are strategies management should adopt to overcome the barriers (A. M. Bashir et al., 2015).

In the Kingdom of Saudi Arabian (KSA) construction industry, Sarhan et al. (2018) identified twenty-two (22) barriers to LC implementation and grouped them using principal component analysis (PCA) in descending order of prevalence. These barriers are traditional practices, client-related barriers, technological barriers, performance and knowledge–related barriers, and financial related barriers. Bayhan et al. (2019) carried out a study aimed at providing a set of key enablers and barriers to LC implementation. 27 enablers and barriers were identified and grouped into 7 major groups, which are financial, managerial, technical, workforce, culture, government, and communication. Based on the relative mean weight of the barriers, the major components among the key categories are lack of top management support, misperception about lean practices, lack of information sharing and integrated change control, stakeholder issues in communication, failure in operational excellence, inefficiency in resource planning, and lack of organizational communication.

Oguntona et al. (2019) assessed the perception of construction professionals in South Africa regarding LC practices, and found that the major barriers to lean are poor culture among project partners, lack of good policies, the complexity of LC process, poor organizational knowledge, and lack of understanding of LC practices. The study further found that the measure for implementing LC are the appointment of lean expert/consultant, education and training of stakeholders, motivation, and commitment of stakeholders, the establishment of policy and regulatory system, and introduction of certification and measurement standards. The study of Adegbembo et al. (2016), shows some LC barriers including lack of lean awareness and understanding, lack of exposure to the need to adopt the lean concept, lack of proper training, difficulty in understanding lean concepts, weak communication among clients, consultants, and contractors, waste accepted as inevitable, and inefficient use of quality standards. The study recommended more awareness campaigns and the need to expose the workers to lean concepts training.

Ahmed and Sobuz (2019) identified and prioritized the challenges of LC implementation in the Bangladeshi construction industry and found that the highest-ranking challenges are the lack of awareness about LC, lack of skills, training, and lean techniques, unwillingness to change the existing culture, lack of management commitment, fragmented and cyclic nature of the construction project and unavailing communication between all project participants. It was recommended that more effort and focus should towards overcoming barriers such as; traditional culture and practice, stakeholder's communication and relationship, quality materials and methods, technological and performance, and knowledge barriers. Similarly, a separate study by Ahmed et al. (2020) in Bangladeshi, found that the major challenges to LC are lack of awareness and skill, poor management, traditional culture and attitude of employees, inadequate resources and equipment, and non-use of modern techniques and technologies.

In the south African construction industry, Oke et al. (2021) found that the major challenges facing the implementation of LC practices are consist of poor culture among project partners, lack of good policies, the complexity of LC process, poor organizational knowledge, lack of understanding of lean construction. The study concluded that LC revolves around attitudes, and recommended for a complete attitudinal change from the key construction participants in the day-to-day activities of LC practices. In a similar but different study, Allu and Emuze (2018) identified inadequate knowledge, lack of proactive improvement actions, and limited lean awareness as the major implementation barriers to LC in South Africa. In the UAE, Kanafani (2015) found that the two major themes of barriers to LC Implementation are lack of

management commitment and lack of stakeholders' commitment. the sub-themes under these major themes are; lack of management commitment (absence of a qualified project management team, inefficiency in the procurement process, and lack of training, education & development) and lack of stakeholders commitment (late involvement in the supply chain, lack of client & consultant engagement in LC, and lack of proper risk assessment & management).

Forty-one (41) major barriers to LC were selected from the reviewed literature and summarised in table 1.

3. METHODS

This study adopted a questionnaire survey approach of construction professionals in the south-south region of Nigeria. The questionnaire is suitable for covering a large area, and it is economical and fast in data collection. The target participants were architects, engineers, quantity surveyors, and builders; who have at least 5 years of working experience in the industry and are engaged in active construction sites at the time of this study. Furthermore, they were required to have knowledge of LC techniques. These criteria were to ensure unbiased and quality data are gathered from the participants. The south-south region is made of six states (Akwa Ibom, Bayelsa state, Cross River, Delta, Edo, and Rivers states), and the population of the professionals in these states was obtained from the previous study (Otali et al., 2020), of 1252. This sample population is equivalent to 197 sample sizes from Krejcie and Morgan (1970) sample size determination table.

The questionnaire has two sections and the first section collected data on the survey participants' basic information. The second section gathered data on the barriers to LC techniques application on construction project delivery. Based on the level of importance of the 41 selected barriers from the literature review, the participants were required to rate the barriers on a 5-point Likert scale (1 = lowest scale, 5= highest scale). The procedure for data collection was through the use of snowball sampling techniques and personal delivery from the researchers and by email. The snowball sampling technique is dependent on referrals and it can increase the sample size (Atkinson R & J, 2001; Heckathorn, 2011). According to Nwaki and Eze (2020), the electronic means of questionnaire survey is environmentally friendly, reduces the volume of hardcopy questionnaires.

At the end of survey participants' sampling, a total of 161 useable responses were received and these represent a responses rate of 81.73%. The response rate of 81.73% is high because follow-up calls were put across to the participants over the 14 weeks duration of the study. The breakdown of the 161 (81.73%) gathered responses by state are (Akwa Ibom=16(9.94%), Bayelsa state=14(8.7%), Cross river=27(16.77%), Delta=39(24.22%), Edo=29(18.01%), and River state = 36(22.36%).

Table 1 Summary of identified Barriers to lean construction

S/N	Barriers to lean	Source(s)
1	Absence of management commitment and support	Bayhan et al. (2019); Ahmed and Sobuz (2019); Kanafani (2015); Sarhan et al. (2018); Movaghar (2016); Adegbembo et al. (2016); Abdullah et al. (2009);Sarhan and Fox (2013);Moradlou and Perera (2017)
2	Poor leadership and management skills	Bayhan et al. (2019); Ahmed et al. (2020); Sarhan et al. (2018); Abdullah et al. (2009); Bashir et al. (2010); Lodgaard et al. (2016)
3	Inefficient use of quality materials	Adegbembo et al. (2016)
4	Roles and responsibilities not defined	Sarhan et al. (2018); Lodgaard et al. (2016)
5	Lack of motivation and incentives	Bashir et al.(2015);Lodgaard et al. (2016)
6	Chosen tools and practices not according to best practices	Lodgaard et al. (2016)
7	Chosen lean tools and practices not adding sufficient value	Lodgaard et al. (2016)
8	Lack of knowledge about lean (philosophy, principles, tools)	Oke et al. (2021); Adegbembo et al. (2016); Sarhan et al. (2018); Bashir et al. (2015); Abdullah et al. (2009); Bashir et al. (2010); Lodgaard et al. (2016)
9	Absence of employee's skill and expertise	Ahmed et al. (2020); Moradlou and Perera (2017)
10	Financial capability and implementation cost	Bayhan et al. (2019); Bashir et al. (2010); Moradlou and Perera (2017)
11	Lack of adequate Lean awareness and understanding	Oguntona et al. (2019); Oke et al. (2021); Ahmed and Sobuz (2019); Ahmed et al. (2020); Allu and Emuze (2018); Adegbembo et al. (2016); Sarhan et al. (2018); Bashir et al. (2015); Abdullah et al. (2009); Sarhan and Fox (2013); Bashir et al. (2010); Movaghar (2016)
12	Employees attitude and organizational culture	Ahmed et al. (2020); Bashir et al. (2015)
13	Limited knowledge of the lean concept	Adegbembo et al. (2016); Oguntona et al. (2019)
14	Culture and human attitudinal issues	Bashir et al. (2015); Bayhan et al. (2019); Oguntona et al. (2019); Oke et al. (2021); Sarhan and Fox (2013); Movaghar (2016), Moradlou and Perera (2017)
15	Lack of cooperation from employees	Bashir et al. (2015)
16	Long time required to implement lean practices	Adegbembo et al. (2016); Abdullah et al. (2009); Bashir et al. (2015)
17	The complexity of the construction industry	Bashir et al. (2015)
18	Delays in decision making	Adegbembo et al. (2016); Sarhan et al. (2018)
19	Misperception about Lean practices	Bashir et al.(2015);Bayhan et al. (2019)
20	Poor communication among stakeholders	Bayhan et al. (2019); Sarhan et al. (2018); Ahmed and Sobuz (2019); Adegbembo et al. (2016)
21	Lack of information sharing and integrated change control	Bayhan et al. (2019); Adegbembo et al. (2016)

S/N	Barriers to lean	Source(s)
22	Poor planning of resources	Bayhan et al. (2019)
23	Failure in operational excellence	Bayhan et al. (2019)
24	Poor knowledge of lean benefits and value	Sarhan et al. (2018); Abdullah et al. (2009); Bashir et al. (2010)
25	Weak connection between clients, consultants and contractors	Abdullah et al. (2009)
26	Lack of good policies	Oke et al. (2021); Oguntona et al. (2019)
27	Complexity of lean construction process	Oguntona et al. (2019); Oke et al. (2021); Bashir et al. (2015)
28	Lack of adequate lean skills, training and education	Ahmed and Sobuz (2019); Bashir et al. (2010); Kanafani (2015); Sarhan et al. (2018); Adegbembo et al. (2016); Abdullah et al. (2009)
29	Waste accepted as inevitable	Adegbembo et al. (2016)
30	Resistance, unwillingness to change the existing culture	Ahmed and Sobuz (2019); Bayhan et al. (2019); Moradlou and Perera (2017)
31	Insufficient resources and equipment	Ahmed et al. (2020)
32	Non-use of modern techniques and technologies	Ahmed et al. (2020); Bashir et al. (2010); Sarhan et al. (2018)
33	Reactive and lack of proactive improvement actions	Allu and Emuze (2018)
34	Absence of a qualified project management team	Kanafani (2015)
35	Inefficiency in the procurement process	Kanafani (2015)
36	Late involvement in the supply chain	Kanafani (2015)
37	Improper risk assessment and management	Kanafani (2015)
38	Lack of client and consultant engagement in lean construction	Kanafani (2015); Adegbembo et al. (2016)
39	The influence of traditional management practices	Sarhan et al. (2018)
40	Fragmented nature of the industry	Ahmed and Sobuz (2019); Adegbembo et al. (2016)
41	Lack of long term relationship with suppliers	Adegbembo et al. (2016); Sarhan et al. (2018); Abdullah et al. (2009)

The collected data were subjected to a reliability test using the Cronbach alpha test. An alpha value of 0.957 was obtained for the assessed variables. This shows a very high level of reliability of the research instrument. Frequencies and percentages were used to analyze the basic background information of the respondents. Factor analysis (FA) was used to analyze the data gathered on the barriers to LC application on construction projects. The FA used principal component analysis (PCA) with varimax rotation as the method of data extraction. Factors analysis was aimed at reducing the variables into a cluster of a manageable and cohesive proportion of different construct. The entire methodological flow is represented in Figure 1.
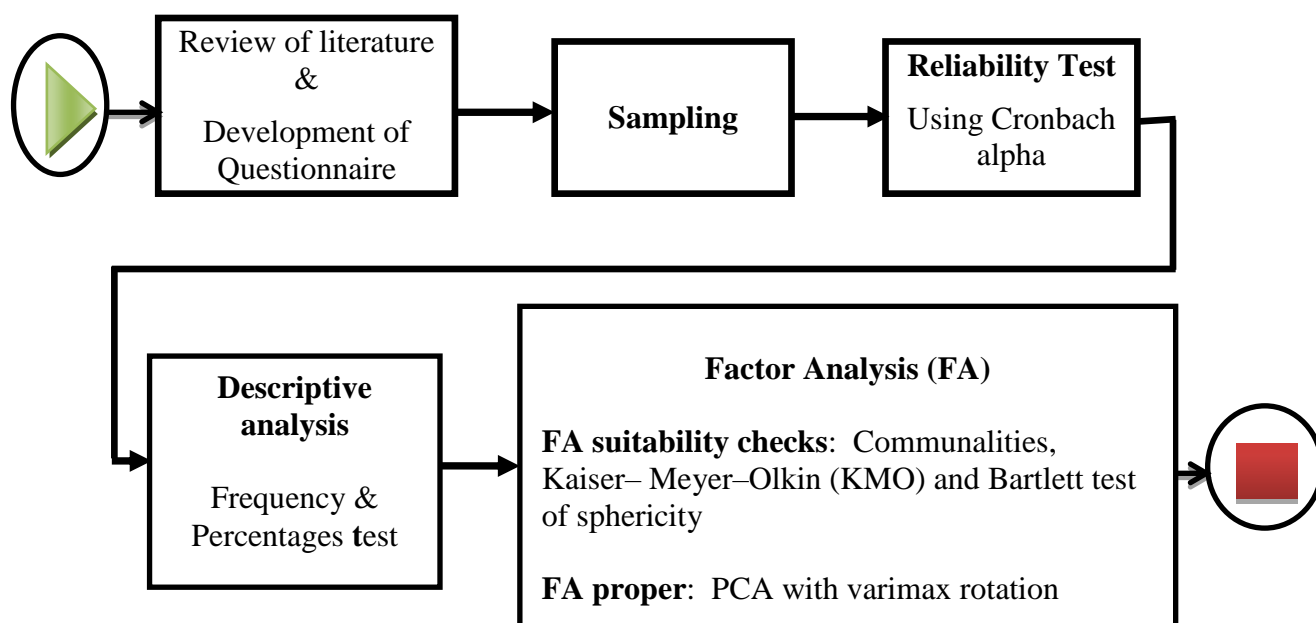
Figure 1 Methodology flow chart

4. RESULTS AND DISCUSSION

4.1. Basic Information of Respondents

The analysis of the basic information of the respondents shows that the survey participants from the private organizations are more by 57.14%, and they are followed by those from the public organizations by 42.86%. By profession, a good number of the participants are Engineers (31.68%), followed by Architects (30.43%), then Quantity Surveyors (24.22%), and lastly, Builders (13.66%). This shows a good mix of the key professionals' employees of construction organizations. The average working experience of the participants is 13.48 years and this fell within the modal and median class of range 11-15years. With 36.02% and 29.81% having bachelor degree (BSc./B.Tech) and Master's degree (MSc./M.Tech.) respectively as their highest academic qualifications, shows that they are educationally qualified to make a meaningful contribution to the subject of this study. Finally, in terms of professional members, 91.30% of the respondents are corporate members of their various professional bodies, and only 8.7% are probationers of their professional bodies. This indicates that highly professional and experienced participants took part in this survey.

4.2. Major Barriers to Lean Construction

Prior to carrying out the factor analysis, the factorability and adequacy of the collected data for the analysis were done. This was achieved regarding the sample size, the number of variables, commonalities, Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, and Bartlett's test

of sphericity. With regards to the number of variables and sample size; the 41 barriers selected from the literature are adequate and this is based on the understanding that there is yet to be an agreement regarding what number of variables is suitable for factor analysis. Also, the sample size of 161 is adequate for factor analysis and this is premised on the suggestions of (Hair et al., 2010; Pallant, 2007; Tabachnick & Fidell, 2007).

Table 2 KMO and Bartlett's Test for Lean Construction Barriers

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.869
Bartlett's Test of Sphericity	Approx. Chi-Square	5006.914
	df	820
	Sig.	0.0000

The maximum and minimum communalities values for the variables are 0.832 and 0.501 respectively and with an average of 0.694. The average communality is above 0.60, and the sample size becomes meaningless in determining sample size adequacy for FA (Pallant, 2007; Taherdoost et al., 2014). Furthermore, variables with a communalities figure of greater than 0.5 fit well in the construct with other variables (Eze et al., 2018). Furthermore, with the KMO value of 0.869 which is above the cut-off score of 0.50 (Field, 2005; Hair et al., 2010) and the Bartlett test with a chi-square value of 5006.914, df=820, and p-value of 0.000 (see Table 2), it can be said that the variables are suitable and adequate for factor analysis.

4.2.1 Factor analysis: Principal component analysis (PCA) and factor extraction

Through the utilization of principal component analysis (PCA) with varimax rotation as the method of extraction, the factor analysis was executed. Six factors were extracted with eigenvalues of greater than 1.0, based on the Total Variance Explained (TVE). The 6 factors extracted accounts for over 50% of the total cumulative variance. This is in line with the proposal from previous studies (Hair et al., 2010; Pallant, 2007; Stern, 2010) (see table 3).

Table 3 Total Variance Explained (TVE) of barriers to lean construction

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cum. %	Total	% of Variance	Cum. %	Total	% of Variance	Cum. %
1	15.84	38.63	38.63	15.84	38.63	38.63	5.62	13.72	13.72
2	3.19	7.77	46.41	3.19	7.77	46.41	4.40	10.74	24.45
3	2.22	5.42	51.83	2.22	5.42	51.83	4.29	10.45	34.91
4	1.87	4.55	56.38	1.87	4.55	56.38	3.99	9.74	44.64
5	1.54	3.77	60.15	1.54	3.77	60.15	2.73	6.65	51.29
6	1.33	3.25	63.40	1.33	3.25	63.40	2.71	6.61	57.91

In the Rotated Component Matrix (RCM), table 4, only variables with a factor loading of greater than 0.50 were extracted (retained) and this is based on the (Spector, 1992) submission. The 6 major components contain items with a factor loading that explained much of the variance than the remaining components.

4.2.2 Categorization and extractor factor discussion

Categorization is determined by the examination of the critical and latent characteristics of the items loading under the components. Where it is difficult to secure a befitting name for components, consideration is given to the items with the highest factor loading under the component under consideration.

In the RCM (Table 4), 8 items were loading under the first components and they account for 38.63% of the total variance explained of the extracted variables. These items are non-use of modern techniques and technologies, lack of adequate lean skills, training and education, poor knowledge of lean benefits and value, lack of adequate lean awareness and understanding, late involvement in the supply chain, improper risk assessment and management, fragmented nature of the industry, and inefficiency in the procurement process. After a critical examination of the items, the component was named *'Technology and Knowledge barriers'*. The construction industry of this day is technology-driven and knowledge is an asset of organizations. The poor utilization of technology in construction has impacted on cost and time of project delivery, thereby leading to more wastage. This is, however, against the philosophy of LC.

Table 4 Rotated Component Matrix (RCM) of lean construction barriers

Variables	Component					
	1	**2**	**3**	**4**	**5**	**6**
Non-use of modern techniques and technologies	0.774					
Lack of adequate lean skills, training and education	0.741					
Poor knowledge of lean benefits and value	0.694					
Lack of adequate Lean awareness and understanding	0.670					
Late involvement in the supply chain	0.576					
Improper risk assessment and management	0.539					
Fragmented nature of the industry	0.527					
Inefficiency in the procurement process	0.504					
Lack of client and consultant engagement in lean construction		0.745				
Lack of long term relationship with suppliers		0.728				
Weak connection between clients, consultants and contractors		0.693				
Waste accepted as inevitable		0.595				
Long time required to implement lean practices		0.549				
Organizational culture and employees attitude			0.803			
Complexity of lean construction process			0.775			
Resistance, unwillingness to change the existing culture			0.625			
Lack of good policies			0.593			
Failure in operational excellence			0.530			
Poor leadership and management skills				0.845		
Absence of management commitment and support				0.721		
Misperception about Lean practices				0.629		
Inefficient use of quality materials				0.604		
Lack of motivation and incentives				0.578		
Lack of cooperation from employees				0.574		
Absence of employees skill and expertise				0.569		
Poor communication among stakeholders					0.696	
Lack of information sharing and integrated change control					0.604	
Roles and responsibilities not defined					0.559	
Financial capability and implementation cost						0.654
Reactive and lack of proactive improvement actions						0.732
Limited knowledge of the lean concept						0.717
Complexity of the construction industry						0.515

LC implementation in the construction industry of most nations has suffered a serious setback because of a lack of the basic skills, education, and training on the concepts. Training and

education improve knowledge such as awareness and understanding, knowledge of benefits of lean, among others. This is well documented in the extant construction management literature (Shakil Ahmed et al., 2020; Shakil Ahmed & Sobuz, 2019; Allu & Emuze, 2018; A. Bashir et al., 2010; A. M. Bashir et al., 2015; Moradlou & Perera, 2017; Movaghar, 2016; Oguntona et al., 2019; Oke et al., 2021; S. Sarhan & Fox, 2013)

The adoption level of modern technologies that accelerate construction work and enhance communication is low, and this impedes the communication of LC techniques (Shakil Ahmed et al., 2020). Lack of the basic skills and knowledge on how to use modern technological tools like BIM is a challenge that impacts the successful application of lean principles (J. Sarhan et al., 2018). Zhang et al. (2018) found that BIM which is an innovative technology can be utilized to enhance project performance. BIM helps to detect clashes that can result to rework, thus, eliminating wastages in construction materials, time and cost. The adoptions of LC principles using computer simulation have been found to reduce different types of waste (Nikakhtar et al., 2015). One of the most critical barriers to LC is poor awareness and understanding, and poor knowledge of the benefits and value of the concept (Allu & Emuze, 2018; S. Sarhan & Fox, 2013). According to Ahmed and Sobuz (2019), technological and knowledge barriers were some of the barriers to LC implementation that requires adequate focus towards eliminating because of the level of impact they have on LC application on construction projects.

The second component has 5 items and accounts for about 7.77% of the total variance explained. After an examination of the variables loaded under this component, it was named '*Engagement and relationship barriers*'. The component is comprised of lack of client and consultant engagement in LC, lack of long-term relationship with suppliers, weak connection between clients, consultants, and contractors, waste accepted as inevitable and long time required implementing lean practices. Stakeholders' engagement and relationship issues hinder the implementation of LC practice on construction projects. The implementation of innovative construction management techniques like the lean concept requires the buy-in of all stakeholders and a smooth relationship.

The engagement and relationship barrier reported in this study is in line with the findings of (Shakil Ahmed & Sobuz, 2019; Kanafani, 2015). Kanafani (2015) found that lack of client and consultant engagement in LC is stakeholders' barrier to lean concept. Stakeholder communication and relationship was identified by Ahmed and Sobuz (2019) are barriers to LC. When stakeholders are properly engaged, they will get details of what they are up against. Proper engagement of project stakeholders and good working relationships are a panacea for effective information sharing and smooth workings toward the delivery of construction projects. Ahmed et al. (2020) found that stakeholders' communication and relationships are challenges that need to be overcome in the implementation of LC.

In the 3rd component, 5 items are loaded under it, and they account for 5.42% of the total variance explained. These five items are organizational culture and employee attitude, the complexity of LC process, resistance, unwillingness to change the existing culture, lack of good policies, failure in operational excellence. Following a cursory look at these items that loaded under this component, it was '*Culture and complexity barriers*'. Organizational and employees' culture and the complexity of the construction processes make it difficult for construction organizations to reap the full benefits of LC. Attitudinal issues regarding new techniques are well document in literature (Shakil Ahmed et al., 2020; Shakil Ahmed & Sobuz, 2019). The culture was found among the key issues that impede the implementation of the lean concept on construction projects (Bayhan et al., 2019). Cultural issues and the complexity of the lean construction process, absence of good policies that support LC; were found by (Oke et al., 2021) as the major factors impeding LC implementation in the construction industry of South

Africa. The LC application is not as straightforward as it seems. It involves conscious efforts backed up by a disciplined and dedicated lean team to achieve the lean objectives of waste reduction and value maximization. Resistance and unwillingness to change by some critical stakeholders is another factor that causes drawbacks to LC application on construction projects. Over satisfaction with the existing method of project, delivery is another factor that impedes the use of modern waste minimization techniques like LC. This supports the findings of Ahmed and Sobuz (2019).

The fourth component was named '*leadership and management barriers',* after a critical examination of the items loaded under it. This component has seven items and accounted for about 4.55% of the total variance explained. These items are poor leadership and management skills, absence of management commitment and support, misperception about lean practices, inefficient use of quality materials, lack of motivation and incentives, lack of cooperation from employees, absence of employee skill and expertise. Leadership and management commitment and support are key to entrenching the best practices in the construction industries of nations. A driving force to lean implementation is leadership style and management support. Poor management support is well document in the extant literature as a critical barrier to lean concept (Shakil Ahmed & Sobuz, 2019; Lodgaard et al., 2016; Moradlou & Perera, 2017; Movaghar, 2016; S. Sarhan & Fox, 2013). The most important barrier to innovation adoption in any industry is leadership and management support. Lodgaard et al. (2016), Ahmed and Sobuz (2019), and Sarhan and Fox (2013) found that insufficient commitment from management and poor leadership are among the major barriers to LC. Moradlou and Perera (2017) and Movaghar (2016) also reported that the lack of top management support is one of the key factors that impede LC. It is the responsibility of management and leadership to provide the enabling environment for the implementation of the lean concept. This will be possible when they invest in it, motivate the workforce by way of increasing their knowledge, skills, and understanding of the concept. Also, they are responsible for the provision of the needed tools, equipment, and technologies that drive LC on construction projects.

Three items loaded under the 5th component and account for 3.77% of the total variance explained. These three items are poor communication among stakeholders, lack of information sharing and integrated change control, roles and responsibilities not defined. This component was named '*Communication barriers'* based on the examination of the items loading under it. It is through communication that new knowledge and concepts are shared. Effective communication improves stakeholders' engagement levels and relationships. The lack of effective communication is a barrier to LC. Unavailing communication between all project participants was reported by Ahmed and Sobuz (2019) are major barriers to LC. One of the major categories of lean barriers identified by (Bayhan et al., 2019), is communication. Communication issues among stakeholders and the lack of effective organizational communication is a major limiting factor to LC practices in construction projects. Weak communication among clients, consultants, and contractors were among the barriers to lean identified by (Adegbembo et al., 2016). Communication plays a critical role in construction project delivery. Poor and ineffective communication has been blamed for so many problems facing construction projects. Poor communication is linked to disputes, claims, errors, rework, safety issues, cost overruns, qualities issues, among others. For LC to be successfully implemented, effective communication and information sharing are key success factors in project development.

Four items were loaded under the 6th component and it accounts for 3.25% of the total variance explained and the 63.40% cumulative variance of the extracted factors. The items loaded under this component are; financial capability and implementation cost, reactive and lack of proactive improvement actions, limited knowledge of the lean concept, and complexity of the

construction industry. These items were closely related to cost, and this led to the naming of the component as '*Financial barriers*'. Finance is an important driver for innovative techniques in the construction industry of nations. The lack or insufficiency of finance means that a lot of innovative tools and techniques will not be applied to construction. This result is in line with the findings of previous literature (A. Bashir et al., 2010; Bayhan et al., 2019; Moradlou & Perera, 2017; J. Sarhan et al., 2018). Moradlou and Perera (2017) found that financial capability is a major barrier to LC implementation in construction. Bashir et al. (2010) in the UK found that financial issues are among the major barriers to LC implementation. Sarhan et al. (2018) and Bayhan et al. (2019) also found that financial related barrier is among the major categories of LC implementation barriers. Finance is the 'life blood' and the 'oxygen' of the construction project. Quality materials and labor and equipment, technologies are procured using finance. The lack of or inadequacy of it could lead to project abandonment, claims, and disputes.

From figure 1, it can be seen that technology and knowledge barriers are the most critical barriers to LC, and this is closely followed by leadership and management barrier, then culture and complexity barrier, engagement and relationship barrier, financial barriers, and lastly communication barriers. These reflect the major barriers that need to be overcome by construction organizations for the full potentials benefits of LC techniques to be achieved.
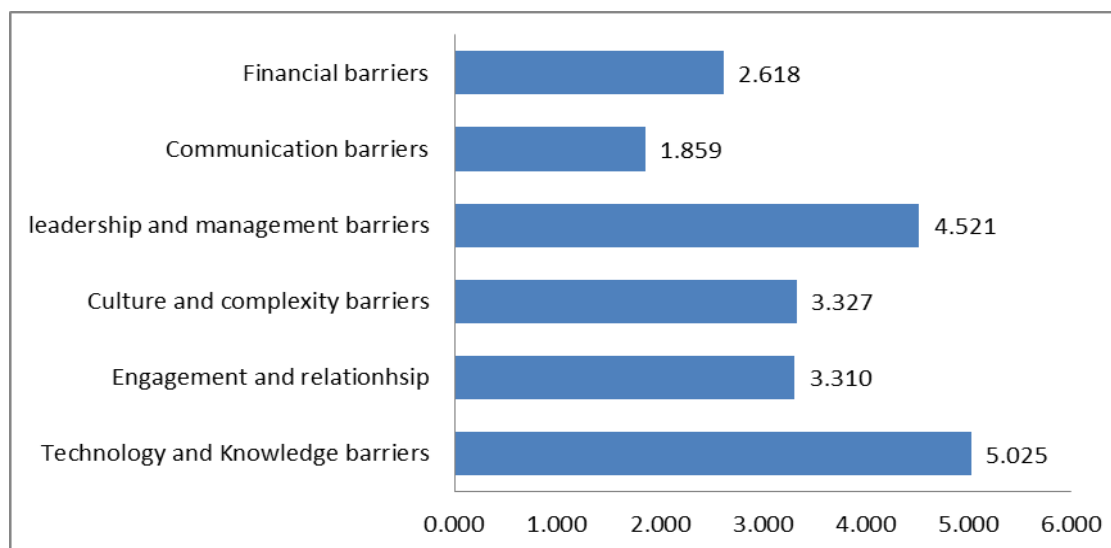
Figure 1 Weighting of factor loading

From the major cluster of barriers of LC found in this study, the following recommendations were made;
- Adoption of modern technology for running the affairs of construction projects. Construction organizations should accept IT-based technology to avoid wastages and loss of values. Management has a role to play in seeking collaboration in areas of technology. Furthermore, knowledge-building activities should be entrenched; this will increase awareness and understanding of the lean concept among construction stakeholders.
- There should be sufficient engagement and a balanced and healthy relationship between the clients, consultants, contractors, and other stakeholders. This will improve communications and understanding of new concepts like lean the approach. Opposition to lean implementation is minimized or even eliminated when there are healthy relationships among stakeholders.

- LC practices should be made an integral part of the functioning and operations of the construction organizations. This will improve the adoption level of LC and better project performance.
- Adequate management support and leadership are key to the successful implementation of the lean concept in the construction industry. Support for technology, training, and making lean part of the organizational culture is a driving force for speedy diffusion of the lean concept among construction professionals and other employees.
- Efficient and effective communication should be provided for the smooth transfer of lean ideas within an organization. Management has a role to play in ensuring smooth information sharing and data dissemination.
- Finance is the 'life blood' of any project; no project can succeed without adequate financing. Following the Lean techniques judiciously is costly and time-consuming, and requires a lot of commitment and resources. LC practices should be seen as an investment with huge benefits.

5.   CONCLUSION

This study was set out to assess the major barriers to LC application on construction project delivery, to suggest possible measures for overcoming the barriers. By utilizing a well-structured questionnaire, through electronic means and snowball sampling techniques, data were collected from construction professionals in the south-south, Nigeria. Appropriate analytical tools were adopted and the study was able to make meaningful findings.

The study found that the major barriers to LC are technology and knowledge barrier, leadership and management barrier, culture and complexity barrier, engagement and relationship barrier, financial barriers, and communication barriers. The existence of these barriers in the construction industry of Nigeria and other developing countries of Africa have been blamed for the persistence of time and other resource wastages and loss of value that characterized the delivery of construction projects. These are also amongst the leading causes of time and cost overruns, quality degradation, rework, materials waste, safety issues, efficiency problems, and claims and disputes.

A critical driver of innovative construction methods is the use of modern technology and knowledge. Management and leadership and organizational culture influence the successful adoption of LC practices in the construction industry. LC is an innovative technique for managing organizational and/or project resources so that non-value-added efforts are avoided in the quest to maximize value and better project performance.

These key barriers to LC will enable managers of construction organizations and projects to better prepare for the challenges ahead, especially as they have to do with the reduction of wastages and maximization of projects and value. This study adds to the few existing bodies of knowledge on LC, especially in a developing country including Nigeria.

6.   LIMITATION AND FUTURE RESEARCH DIRECTION

This study was carried out in the south-south region of Nigeria, and this is a critical limitation toward the generalization of the findings. In addition to the geographical boundary, the number of variables assessed, the sample size, and the sampling method are other limitations of the study. A similar study could be carried out in other zones of Nigeria or developing countries, especially of Africa, with similar social-economic dynamics like Nigeria. Such a study should consider larger sample size and number of variables and other sampling techniques. This will make data available for comparison purposes. Furthermore, a detailed investigation should be

carried out on technology-specific barriers to lean adoption in other zones or countries. In addition, leadership and management are key drivers of innovation, what management style is suitable for lean concept implementation in construction? This question requires an answer and this is will only be possible through a survey. Rework has come to stay with the construction industry, and it has been identified as a major cause of poor project performance, especially as it ensures that the time, cost, and quality objectives of projects are unsatisfactory. A study to develop a lean framework for managing rework could be embarked upon.

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TRADITION OF PETANG MEGANG AND ITS INFLUENCE IN CHANGING THE SIAK RIVERSIDE IN PEKANBARU

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ABSTRACT

Siak River is the main river in the capital city of Riau Province, and it plays a vital role in the history and the development of the city of Pekanbaru. People use the river as the source of water, transportation, and even the traditional ceremony of Petang Megang, which indicates the close connection of Pekanbaru people with the river. The Siak riverside is the center of the city, with the old town, markets, settlements, and the royal house located near the river. The community's attachment to the river can be seen through Petang Megang, which is known as a tradition to clean and purify the body and soul to welcome the holy month of Ramadan. During Petang Megang, many people go to the river, perform mandi balimau and even hold competitions and festivals that attract tourists. This paper discusses how Petang Megang reflects the connection of local people to the river and influences the spatial form of the Siak riverside. The findings show that since there are some changes in the practice of Petang Megang, such as boat competition and music festivals, the government develops the Siak riverside not only to accommodate Petang Megang but also to attract tourists. Unfortunately, the development limit access of local people to the river.

Keywords: Infrastructures; Petang Megang; Riverside; Spatial Form; Transformation

1. INTRODUCTION

Siak River is located in Pekanbaru, the capital city of the Riau Province. It is vital for transportation, economic, and even cultural developments of the city of Pekanbaru. As the deepest river in Indonesia, people in Pekanbaru use the river to connect cities and regions. The river stretches from West to East, connecting the city of Bukittinggi in West Sumatra to the Malacca Strait. There are many settlements, government centers, historical sites, markets, and trading centers alongside this river. People in Pekanbaru are also closely related to the Siak River in their daily lives.

From its geographical condition, the Siak River also divides the city of Pekanbaru into two parts, the northern part of the river – a basecamp of the Caltex Oil Company– and the southern part of the river – as the old city. The riverside is known as a historical site as well as a trading center. Pekanbaru is located in the middle of Sumatra Island with the Siak River as the main transportation route; it makes Pekanbaru known as a transit city and a trading port in Sumatra.

Figure 1 shows the strategic location of the Siak River and the position of two important bridges that connected the northern and the southern part of Pekanbaru. The addition of infrastructure strengthens the meaning of Pekanbaru as a transit city for many Sumatra regions, including Malaysia and Singapore. As a transit city for local and regional trading, the government provides some infrastructure to help traders do their business. Some of these infrastructures are new ports, streets, and commercial buildings such as the central market in the riverside areas to accommodate the growing activities near the Siak River. People living near the river also do some activities such as bathing, washing, fishing, and even traditional ceremonies that connect people and the Siak River. There are also some bridges located over the Siak River and a new toll road, Trans-Sumatera Toll Road, connecting Aceh Province in the North to Lampung Province in the South of Sumatra. In short, the Siak River is significant for the city, and the riverside areas become essential infrastructure for people in Pekanbaru.
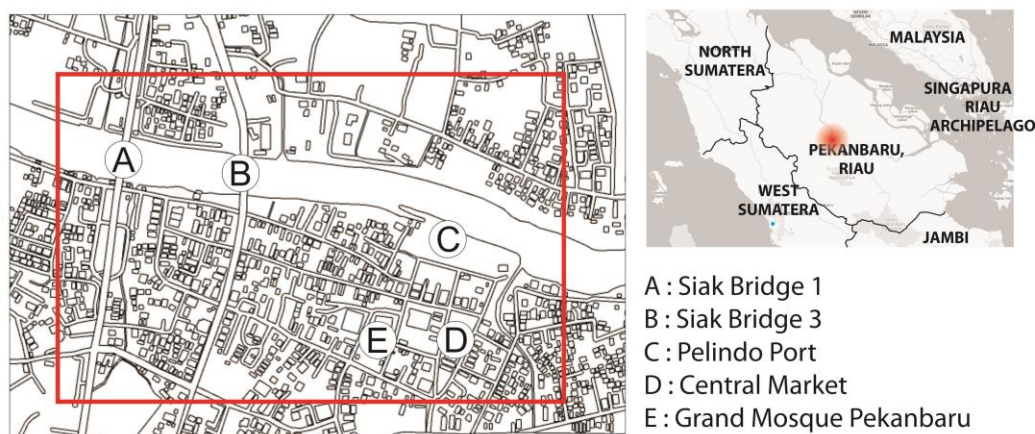
Figure 1. Maps of the Siak River in Pekanbaru, Riau (source: authors' illustration)

The area between Siak Bridge 1 and Siak Bridge 3 is a dense area where people do their daily activities. The old city is located in this area, including the Sultan of Siak lives and the oldest commercial buildings. Several old buildings located in the area are parts of Malay architectural heritage, and they have high historical and cultural values. Besides, there are some trading centers and settlements in the area.

Studies of urban places have evolved from understanding the relationships among urban forms, activities, and imagery (Montgomery, 1998) to include human behavior and social construction (Morgan, 2010). Architectural historian Spiro Kostof used the term "city process" to remind city planners and designers of a never-ending process of becoming an ideal city (Kostof & Castillo, 1999). He asserts that patterns and elements of the city are formed by social, political, economic, and cultural forces built through the historical process. Here, the city's physical form can never be separated from the social contexts, as a matrix organized in daily life.

A combination of urban forms, user activities, and meanings people give to the place create a meaning place in urban space (A. S. Ekomadyo et al., 2018). Human factors such as social and cultural beliefs, traditions, and religious practices may contribute to the spatial forms of the built environment (Al Husban et al., 2021).

Petang Megang is one of the original traditions of Riau Province, which symbolizes a connection between people and the river. This tradition includes cleansing and bathing processions or called mandi balimau, conducted before the holy month of Ramadan (Moekahar, 2018). This ceremony attracts people living in Pekanbaru and the surrounding areas to come

and join the tradition. At first, this tradition has a focus on cleansing and bathing activities. Later on, people in Pekanbaru celebrate Petang Megang as a big festival and add some new activities such as Boat Festival, traditional competition, and visiting the historical site and old tombs near the Siak River.

Like most traditions, Petang Megang also has some changes over time. There have been some changes in how people use the riverside and how people connect to and value the river, seen through Petang Megang. Previously, people in Pekanbaru focused more on the tradition of mandi balimau and gatherings to maintain the relationship among community members. During the Petang Megang ceremony, the cleansing and gathering activities take place on the riverside. During mandi balimau, some people take a bath in the river. Now, the tradition of Petang Megang is more like a big festival. Even though some people still take a bath in the river, most people gather on the riverside areas to see the Boat Festival and other government-supported activities. The local government develops the riverside to accommodate Petang Megang by building additional infrastructure near the river, making a new park below the Siak Bridge 3 to accommodate Petang Megang. This development merges with the importance of Pekanbaru's historical sites. In 2015, there are approximately 5,000 people attended the Petang Megang ceremony (Republika, 2015). This fact proves that Petang Megang invites local tourists to come to Pekanbaru. Since more people use the riverside during Petang Megang and the fact that tourists give some income to the city, the local government build some new infrastructure utilized by the community to carry out this tradition.

Previous studies on the Siak riverside suggest that the area's development should be connected to the physical characteristic of the area, such as aesthetic and health aspects (Suryadi et al., 2016). Some studies relate the development of the riverside with social and cultural contexts (Cheris & Repi, 2017), but it is important to relate more to local contexts like traditional festivals. Some researchers on the Siak River are mainly associated with the Dutch colonial era and the impact of oil industries in Pekanbaru. This research tries to occupy a void in the research of Siak riverside and cultural activity Petang Megang.

The research conducted for this paper is related to Petang Megang that is held on the Siak riverside areas, especially near the Siak Bridge 1 and the Siak Bridge 3. As one of the oldest places in Pekanbaru, this area has more population and historical buildings than other Pekanbaru areas. This paper argues that Petang Megang affects the spatial forms of the Siak River riverside. Through the practice of Petang Megang from time to time, this paper analyses how people use the riverside area and how the development of Petang Megang influences the condition of the Siak riverside. This paper elaborates on some developments in the riverside areas in relation to the tradition of Petang Megang that also attracts local tourists.

2. LITERATURE REVIEW

2.1. The River as an Important Infrastructure for the City

In many civilizations, people tend to choose a place that is the activities center of a region. Settlements often appear at a strategic location, at crossroads, or other locations with easy access, for instance, near rivers, roads, trains, or airports (Sevtsuk, 2012). These locations will allow their economic, cultural, and social activities. Over time, people start to build infrastructure near these locations. People begin to build dwellings, settlements, and infrastructures where they will do their daily activities, and these activities will influence the physical structures of the cities. But they also decide what these structures mean for them and how to use the built (Gibson, 2015). At this point, the city infrastructure plays a role in influencing the city's activities and vice versa.

Development of infrastructure in the cities will bring stable growth to the cities. This process takes time and may create a transformation to the areas. A development generates more activities in the region, meaning that some new buildings and infrastructures are built and even transformed a region. A transformation is a change of appearance, whether in form, character, or function (Wasnadi & Ellisa, 2019). The change certainly follows the needs and actions of human beings. The uses and meanings of spaces connect people to cities and make cities distinct from one another. A distinctive character of space distinguishes one place from another, which is seen as the uniqueness of the place (Norberg-Schulz, 1979). Built environments, whether cities, neighborhoods, or housings, have a role in influencing and shaping space's human activities (Black & Street, 2014; Gibson, 2015). Community activities and even habits and traditions of people will continue to grow and influence the built environment. Therefore, any change in the activities will eventually change the city.

Water resources have also played an essential role in most of the civilizations in the world, and throughout history, the settlement along the water resources become the center of human activities and with their own distinctive identities (Kürkçüoğlu & Akin, 2013; Timur, 2013). The oldest civilization is developed near the river because the river provides drinking water, transportation, agriculture. In the beginning, people who live on the river's banks build their settlements following the river that give them accessible transportation networks and irrigation for plantations. This kind of settlement has orientations towards the river (Havránková, 2014). Rivers provide water and other natural resources, and they also help connect communities and even create recreation opportunities. Rivers also bring comfort to humans, both physically and psychologically, and some traditional ceremonies are held to symbolize the connection between people and the river. Besides their functions in supporting lives, rivers have some aesthetics qualities that promote riverside areas to become tourist attractions. Urban planners now incorporate green spaces, such as urban forests and riverside parks, as a form of "green and blue" infrastructure that supports public and ecosystem health (Vollmer & Grêt-Regamey, 2013).

2.2. The Connection of Pekanbaru People with the Siak River

There are some explanations for the name of the Siak River. The name of Siak derives from local plants or bushes that grow near the river in the location of the former kingdom of Siak. That is the meaning of the word "siak-siak," taken for the kingdom's name. Local people in Riau usually use this kind of plant as medical and fragrant ingredients.

Siak River has a length of 370 km and connects several districts. The Siak River goes across Pekanbaru, and this city becomes a well-known transit port for traders from West Sumatera and Malacca. The Siak River is one of the four main rivers in the Riau Province and the deepest river in Indonesia, with an average depth of 20-30 m (Yuliati et al., 2017). Siak River has a long history as the heart of human settlements in Sumatra, even before the colonial era and the mining exploration (Onrizal & Mansor, 2020). However, now, the Siak River's depth is only between 8-12 meters (Sumiarsih, 2017). The emergence of factories and industries and domestic activities around the Siak River causes the river to lose its natural qualities (Onrizal & Mansor, 2020).

Siak River plays a huge role in the development of Pekanbaru city. Historically, Pekanbaru City is one of the towns that emerges from the river. The area is the core area of Pekanbaru municipality, formerly known as the Senapelan area (Depdikbud, 1977). In the eighteenth century, the Senapelan region was located on the Siak River banks and became a market for Minangkabau traders. Over time, the area has been developed into a crowded residential area and transit for shipping. The development of Senapelan was also very closely related to the development of the Kingdom of Siak Sri Indrapura. In 1762, Pekanbaru was established as the

Siak kingdom's capital, a separate part of the Malay empire after the Portuguese conquested Malacca in the sixteenth century (A. S. Ekomadyo et al., 2018). During this time, the function of the Siak River as a transportation route had significantly increased.
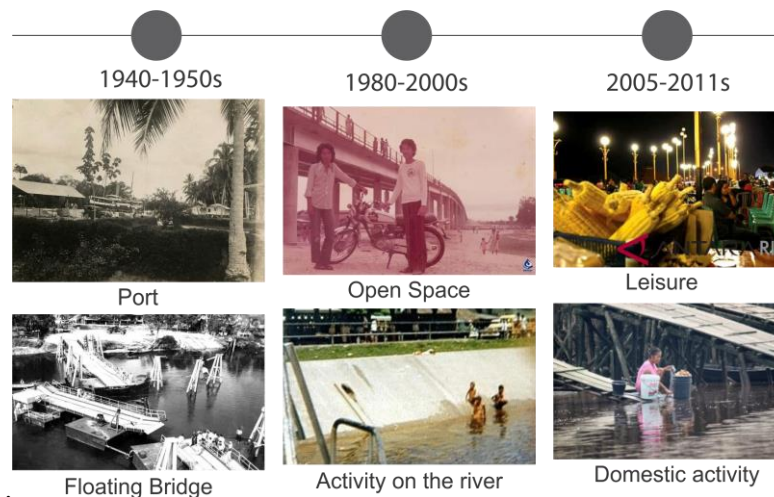
Figure 2. How Pekanbaru's peoples use the Siak River
Source: (Dispusip Pekanbaru, n.d.)

For several centuries, the Siak River was the center of Pekanbaru city, as depicted in Figure 2. As a transit city for traders, the government tries to provide some infrastructure to help traders do their business. Infrastructure development and the arrival of traders from various regions make the waterside area crowded. Many traders start to build houses and buildings for their trading activities. Government builds some infrastructure such as ports and markets alongside the river to accommodate the growth in the economic sector.

2.2. The Tradition of Petang Megang

There is usually a connection between people and the river that has to support the city and the community. This kind of connection can be seen through habits, cultural rituals, and traditions performed by the community. By conducting habits and traditions, people turn space into a meaningful place. In the context of the river, habits and traditions are an attempt to show and symbolize the relationship between people and the rivers. To understand the connection between people and the river, it is necessary to identify the community's place attachment to the river. The concept of an attachment to a certain place (sense of place) can be understood as the quality of human connection with the area. Sense of place is also a combination of characteristics that make a place special and a unique experience on landscapes, local knowledge, and traditions about the site (Aziana et al., 2016).

Each city has its unique character and identity that differentiate it from other cities (Garnham, 1985). The unique character and identity can be seen from the geographical location, language, culture, and tradition. These particular local attributes will produce a sense of belonging to encourage people to maintain their traditions and sense of place and an emotional connection between people and their lives (Herliana et al., 2017).

Tradition means a belief and a habit within a group of people passed down to some generations. Tradition generally refers to some accumulation of past practices or beliefs passed on by parents or authorities, which are re-run or rethought by agents through at least three consecutive "generations" (Jacobs, 2007). Culture represents shared values and traditions, and the meaning of traditions is defined by the people who share the values. There is a possible change in a

tradition. In relation to a festival or an exhibition, a process to create and accept new value is not solely constructed by the authorities, and rather it is an ongoing process modified by users and visitors (Lukito, 2016).

Petang Megang is one of the original traditions of Riau province, especially performed by people living in Pekanbaru and the surrounding areas. This tradition is a symbolization of a clean ceremony or bathing to welcome the holy month of Ramadan. The word *petang* means afternoon, and *megang* means the time between afternoon and dusk. There are differences regarding the emergence of the tradition of Petang Megang. First, Petang Megang is originally came from the Pelalawan region in Riau (Efni, 2017). Second, *mandi balimau,* as part of the tradition of Petang Megang, is believed to be originated from Batu Belah, Kampar Regency during the 1960s, and even the original tradition may come from West Sumatra (Pebrianto et al., 2019).

The essence of this Petang Megang tradition is *mandi balimau*. The word *mandi* means taking a bath or cleaning oneself, while the word *balimau* means lime water (Efni, 2017). The idea of *mandi balimau* is to cleanse the human body and purify the heart to welcome the holy month of Ramadan (Moekahar, 2018). Like most traditions, there are also some changes in Petang Megang, such as how the way it is performed and the values.

3.   METHODS

Since this paper aims to discuss how the tradition of Petang Megang affects the space on the Siak riverside, it is necessary to understand how people use the riverside areas during the ceremony. The paper uses historical and qualitative approaches to investigate how people's activity affects space by the river and causes changes in the area. The historical approach aims to understand the city's development and the connection among people, their activities, and the river. Data collected through literature studies and observation of how people use the riverside are significant in analyzing infrastructure development.

This study results from direct observation of the Petang Megang festival between 2019-2020 and combines the information with secondary sources. The duration of each visit varies from two days to one week. The observations of activities near the Siak River are conducted to understand changes on the Siak riverside and how people are connected to the river in their daily activities, including during Petang Megang. In some observations, the study includes an interview of people living near the river and visitors who see the festival. The discussion on how the Siak River becomes the center of activities from the past to explore how people use the space on the riverside during the Petang Megang. The infrastructure analysis is present by mapping changes near the river from colonial to present by comparing maps, images, and interviews. This analysis helps understand physical changes near the river and interpreting the meaning of the river for people and the city of Pekanbaru. It also means understanding how infrastructures may accommodate Petang Megang tradition despite the rapid development of the riverside.

4.   RESULTS AND DISCUSSION
4.1. A Development of Siak Riverside Area

Long before the name "Pekanbaru" was used as Riau Province's capital, Senapelan was first used as the name of the area on the Siak River banks that we now know as the city of Pekanbaru (Wulandari et al., 2017). The name Pekanbaru in Malay means new market, the word *pekan* means market, and the word *baru* means new. Historically, there are four critical moments in developing the Pekanbaru city structure (A. Ekomadyo, 2013). First, Pekanbaru becomes the capital of the Siak Kingdom in the eighteenth century. The area was also known as

a market for the Minangkabau merchants that had a crowded residential area. Second, the development of Pekanbaru during the Dutch colonial era, especially between 1920-1930. During this period, the city became a center of the coffee and coal industries. Third, Pekanbaru became the new Riau Province's capital in 1959 and became one of Sumatra's fast-growing cities. Fourth, during the decentralization era and the Sijori Growth Triangle (Singapore-Johor-Riau) declaration in 1990 that has enhanced the meaning of the city in economic and trading activities.

During the first development, Pekanbaru was designated as the Siak Kingdom's capital in 1762, led by Sultan Alamuddin Syah after the Portuguese took over Malacca in the sixteenth century (A. S. Ekomadyo et al., 2018). Raja Muda Muhammad Ali continued developing the Senapelan area and created a market on the Siak riverside. The market expected by Raja Ali eventually became more developed and crowded. The traders no longer passed the Petapahan route but passed through Senapelan (Wulandari et al., 2017). If the economic growth has developed, then developments in other fields also grow along with the progress and economic growth.

The second development era was during 1920-1930 when the Dutch East Indies government regulated Pekanbaru. During that time, Pekanbaru grew bigger, especially in fulfilling the increasing world demand for rubber supplies. Sumatra became one of the important rubber plantations, and Pekanbaru was an important transit city for rubber trading. Furthermore, the oil began to be explored in Pekanbaru, such as in 1924 by Standard Oil Company of California. In 1930, Stanvac Oil Company and Nederlandsche Koloniale Petroleum Maatschappij (NKPM) also formally explored oil in Pekanbaru and put the city as an important economic source. During these decades, urban infrastructure in Pekanbaru started to develop rapidly to support plantations and the oil industry. The authorities built some new ports along with the Siak River and the Simpang Tiga Airport in Pekanbaru.

The third development era was when Pekanbaru became the Riau Province's capital in 1959 (A. S. Ekomadyo et al., 2018). At first, its capital was Tanjung Pinang in Riau Islands, and then it was moved to Pekanbaru. As the capital city, the government of Pekanbaru began to build many facilities and infrastructure and established Pekanbaru as the center of the Riau government.
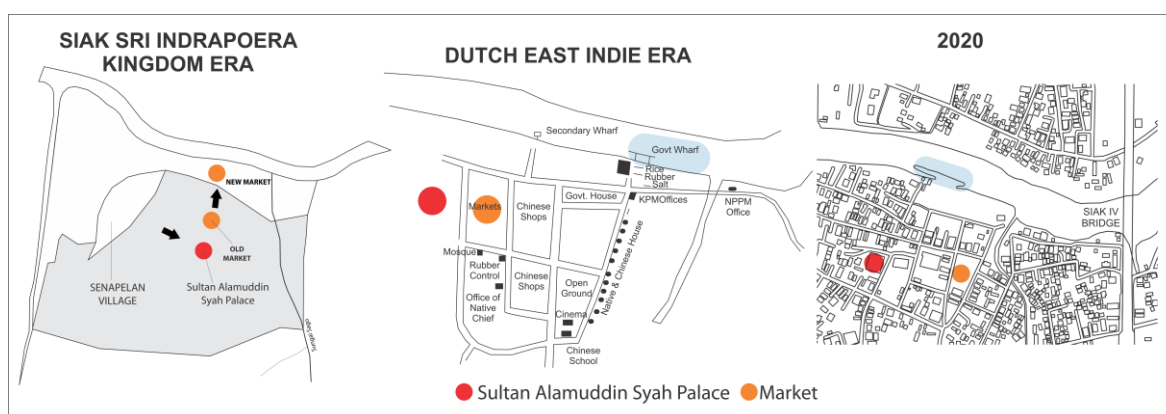
Figure 3. The growth of the Siak Riverside
Source: Adapted from (Depdikbud, 1977; Perpustakaan Nasional, 1933)

The fourth development was when there was a decentralization policy in 1999 (A. S. Ekomadyo et al., 2018). Local incomes were increased since 2000. With the development in economic activities, the role of Pekanbaru as a transit city was also significantly increased. The development of the Singapore-Johor-Riau growth triangle improved the economic activities and

profits of Pekanbaru as a transit city. There were rapid development in the city center and the surrounding areas dominated by commercial facilities and new settlements.

Since the Siak Kingdom period, the Siak Riverside area experiencing rapid growth with some roads, ports, markets, and settlements are built to help people in Pekanbaru to do their activities, especially on Siak riverside as the center of the city. Previously, the Siak River area was the center of the city and the economic activities such as Kampung Bandar, Kampung Dalam, and old market. Due to fast social and economic development, the city expands towards the North and south. Some new infrastructures and settlements are built with the river as the main orientation. Depicted in Figure 3 is a development of the Siak riverside as the center of people's activity in Pekanbaru. During the Siak Indrapoera Kingdom era, important places such as a palace, markets, and the Senapelan Village were built near the river. During the Dutch East Indies era, the Dutch built infrastructure such as roads, ports, schools, and housing to accommodate the city's growth. As a result, the areas near the river became crowded areas. The center of activities also developed according to new roads, government centers, and markets. There were some new business centers, and local people are needed to adapt to the changes. The orientation of buildings changed according to the existing roads and business centers. Places, whether markets, government centers, or neighborhoods, change the city's shape and how people live in a way these buildings attract new activities.

4.2. Petang Megang Tradition and Its Influence on the City Infrastructure

Petang Megang has some sacral and traditional values, such as cleansing both body and soul, reflecting the importance of cleanliness and spiritual purity (Moekahar, 2018). In addition, the ceremony has some processions:

1. People gather near the river and eat together or called *makan bajamba*. Community and religious leaders, government officials, respected people, and the general public come to the riverside and greet each other. The ritual starts before the midday prayer.
2. After the midday prayer, *mandi balimau* is conducted with some community leaders, royal families, and government officials lead the procession. The general public then follows the process, and they head to the river to cleanse themselves both physically and spiritually. Not only locals but tourists are welcome to join in this *mandi balimau* tradition. Aside from washing one's physical body, *mandi balimau* is also intended to cleanse all negative thoughts in the mind and hearts.
3. During the ceremony, people will shake hands as an expression of forgiveness for each other, taken from Islamic tradition in the area.
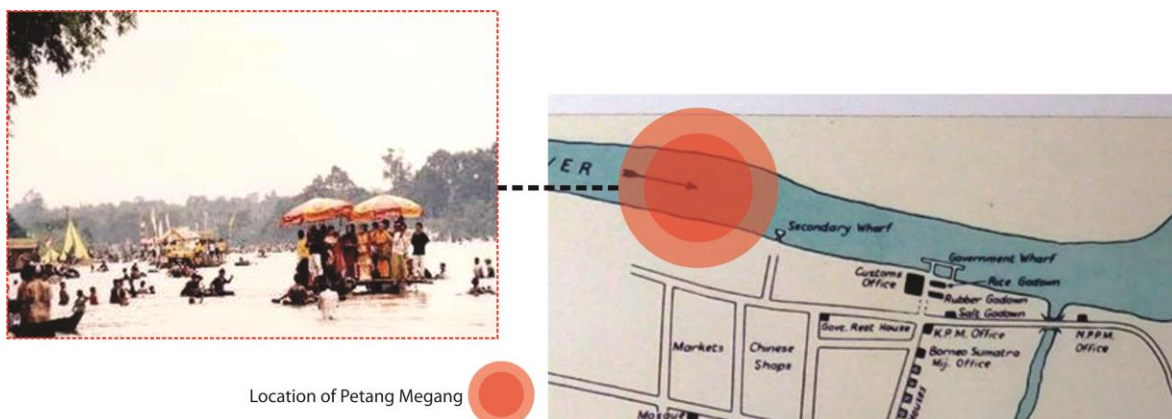

Figure 4. The location of Petang Megang held (Source: National Library)

During Petang Megang, the river becomes the center of the activity (Figure 4). People use the riverside to prepare for the ceremony and gather with families and friends. It is then necessary to have clear areas near the river so that the Petang Megang activities do not use settlement areas. Petang Megang, at first, only focuses on the activities of *mandi balimau* and gathering. Some people use boats or canoe to bring them to the river.

But in recent times, the gathering among community members, especially when the government and the religious leaders are present, is held under a tent on the riverside. The whole procession attracts tourists to Pekanbaru. According to Republika, in 2015, approximately 5000 people attended the Petang Megang ceremony.
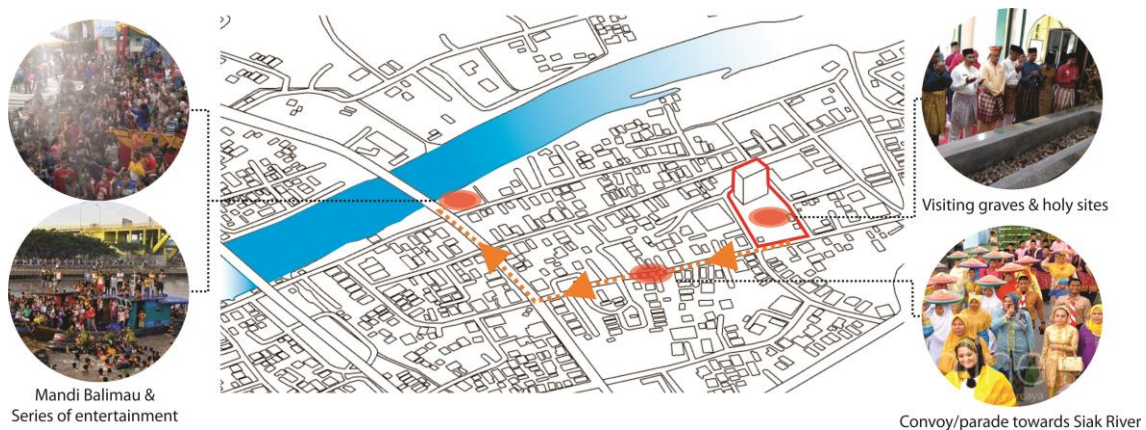
Figure 5. The process of Petang Megang now (Source: authors' illustration)

Now, Pekanbaru Cultural and Tourism Office is the organizer of the Petang Megang tradition. Even though people still perform *mandi balimau*, there are some changes in the event. As depicted in Figure 5, Petang Megang now includes visiting graves and holy sites, or called ziarah, as a symbol of a connection to the ancestor. One of the important graves is the Siak Kingdom sultan's grave, located not far from the Siak River. Visiting the sacred graves is conducted between Zuhur and Ashar prayer times. People then perform Ashar pray in the Pekanbaru Grand mosque, located 850 meters from the Petang Megang location. After that, there is a parade towards the Siak Bridge, and when people reach the riverside, they perform the ritual bath together. To enliven Petang Megang, the organizer usually presents a series of entertainment, including a duck-catching race on the Siak River. With Petang Megang, the Siak riverside arguably becomes the most important tourist destination in Pekanbaru. Fun attractions and competitions such as the sampan festival and music concerts add up the Petang Megang ceremony

The Siak River has the potential for the development of tourism areas on the riverside. To support Petang Megang as both a traditional ceremony and tourist attraction, the local government constructs several river basin infrastructures. The government limits and organizes access to the river by creating barriers and fences between the river and the settlements (see Figure 6). The development of the riverside as a tourism area is meant to revitalize the river's function and develop tourist attractions. The government builds the bridge over the Siak, some new access to the river, pedestrian paths, the tourist market, and a remnant of the Kingdom of Siak as part of the revitalization of the riverside areas. The Waterfront Park is located in the waterside area of Siak River that also interconnects with the historical traces of the Siak Kingdom. Just below the Siak III Bridge, there is a green open area for the local community or known as the city park. This park is quite spacious and has public facilities so that people can

enjoy the good scenery of the Siak River (see Figure 6). In short, the riverside now provides cultural attractions, culinary and recreation centers, and transportation for the city of Pekanbaru.

a) Tuan Kadi House in the historical site   b) Waterfront Park near the Siak Bridge 3
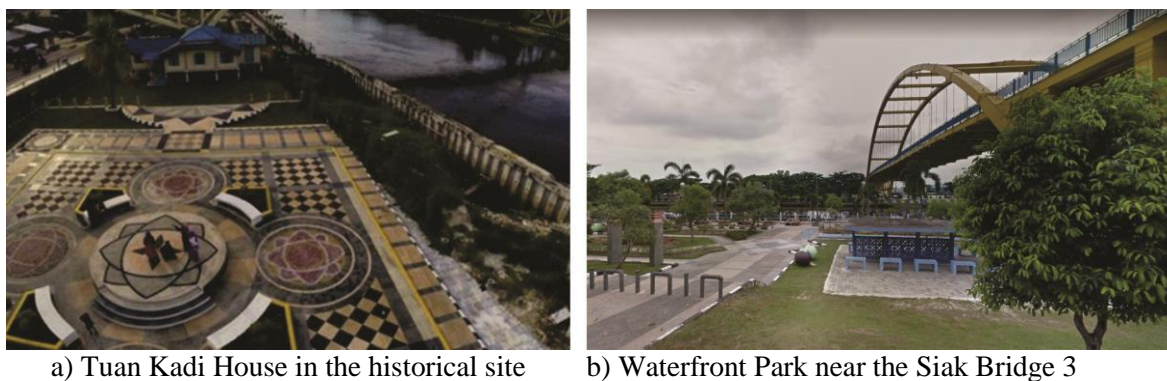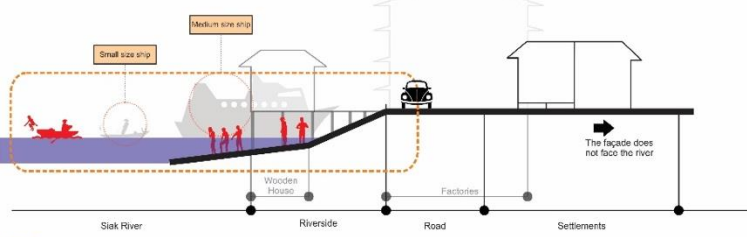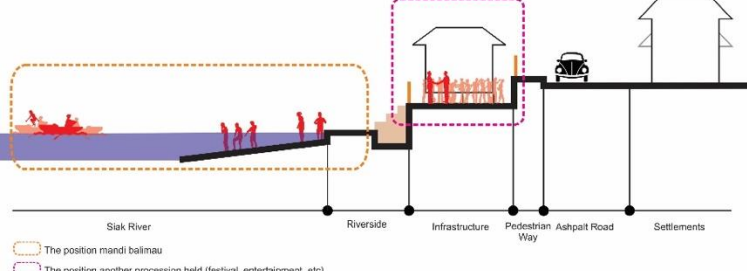
Figure 6. Some infrastructure built by the government (Source: google maps)

Table 1 shows the development of the Siak Riverside area and the connection with Pegang Megang from the Siak Kingdom to the Reformation Era. It seems that some development of urban infrastructure and settlements occur in this area. During the era of the Siak Kingdom, local people performed Petang Megang more as individual and small group activities and freely used the river. With the development of riverside for new settlements, and commercial areas during the Dutch Colonial era, some large ships began to pass through the region. The increasing activities near the river and the fast development in the area caused water and air pollutions. Although local people still performed Petang Megang as individual and small group activities, some people lost their interest in *mandi balimau*. After the reformation era in 1999, Pekanbaru began proclaiming the concept of Waterfront City for the city development and added the tradition of Petang Megang as the annual cultural event for tourists. Local government started to build parks, organizing access to the river, historical sites and tourist centers.

Table 1. Comparison of the tradition of Petang Megang and the use of Siak riverside from the Siak Kingdom to recent times.

CONDITION OF THE SIAK RIVERSIDE	Petang Megang Tradition
The Siak Kingdom Era	Petang Megang started to exist with *mandi balimau* as the main activity. Some local people living near the river went to the River. The infrastructure of the riverside consisted of mostly natura elements.
	Local people continued to carry out Petang Megang as usual and sometimes by taking their boats to do *mandi balimau*. The Dutch and local government developed the riverside and some commercial buildings were built along the riverside. Port activities

The Dutch East Indies Era	were intensified with large ships came through the Siak River.
Post Independence Era (Circa 1970)	Local people still used the river for Petang Megang but due to crowded settlement, traffics, water and air pollution in this area not so many people join the ceremony. There were some new settlements and commercial centers built near the river.
After Reformation Era in 1999	Pekanbaru began applying the concept of Waterfront City as the development theme and included Petang Megang as the annual event. New infrastructures were built, mostly in relation to tourism. With the development of the riverside, access to river was limited.

On the one side the development of the infrastructure is successful in inviting tourists during Petang Megang. On the other side this infrastructure local people experience some downfall in accessing the river. For instance, the parks built near the river cause difficulties for people to access the river. Local residents living near river choose to use the river outside the park and away from their settlement areas.

5. CONCLUSION

Siak River is the most important element of Pekanbaru, and it plays a vital role in the history and transformation of Pekanbaru. The Siak River has a rapid development and makes the Siak River the center of Pekanbaru. It is used as a transportation and transit area that results in development and the riverside areas. The community's attachment with the river indicates the people of Pekanbaru carry out a special relationship between Pekanbaru people and the Siak River with many activities and traditions.

Petang Megang is one of the original traditions from Riau. In this tradition, a purifying tradition is held near the river. During its practice to welcome the holy month of Ramadan, there are some processions of Petang Megang that connect people with the river. This paper has discussed how the tradition of Petang Megang affects the spatial form in the riverside area, especially to accommodate people's activities during Petang Megang. In its development, the practice of Petang Megang has undergone several changes. At first, this tradition focuses mainly on the river with *mandi balimau* and the gatherings. Nowadays, Petang Megang is more like a festival for local people with new attractions such as the sampan and music festivals that attract tourists. The way the community changes the practice of Petang Megang also affects the waterside area in a way people need clear access and place on the riverside areas.

The findings suggest that Petang Megang includes some changes in its procession and influences how people treat the river. To accommodate Petang Megang, the government changed the Siak riverside and added new infrastructures such as new parks, roads, and markets. Petang Megang shows a strong community attachment to the river, and people maintain the ceremony as part of their tradition. The infrastructure developments may accommodate the current needs of space. Still, there should be good planning for the riverside

to accommodate the audience, the tradition, and a potential change in its processions and the riverside use.

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SATISFACTION WITH DWELLING UNIT ATTRIBUTES AND INFRASTRUCTURE WITHIN SELECTED PUBLIC HOUSING ESTATES IN NORTHERN NIGERIA

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ABSTRACT

This study assessed satisfaction with dwelling unit attributes as well as support services and infrastructure within public housing estates across Northern Nigeria as such studies are rare in literature but important for design and policymaking. Results of descriptive statistics, Principal Component Analyses and Regression from 125 respondents in Abuja, Dutse, Sokoto, Gombe and Potiskum revealed that support services and infrastructure notably water supply and waste disposal were inadequate. Although residents were fairly satisfied with their dwelling units (M 3.13), water supply influenced satisfaction ratings for service-related spaces including baths, toilets, cooking and storage. Other areas of dissatisfaction were number of bedrooms, quality of construction and sizes of living spaces. Residents were most satisfied with quality of natural lighting, ventilation, location of houses, noise as well as privacy levels. Results from PCA revealed that residents view satisfaction with their dwelling unit attributes and infrastructure in terms of design and cost, services and indoor environmental quality as well as electricity supply and noise levels. These three factors emerged as significant predictors of satisfaction with dwelling unit attributes and infrastructure, F (20.54, 18), p=0.000, R^2=0.777, in a model that included tenant characteristics. Findings imply that inadequacy in water supply requires urgent attention within public housing estates in the region. Importantly, user perception in terms of the three predictors of satisfaction ought to guide design of future dwelling units within public housing estates in Northern Nigeria.

Keywords: Dwelling units; Infrastructure; Northern Nigeria; Public Housing; Satisfaction

1. INTRODUCTION

Housing is a critical component of sustainable and resilient built environments especially in developing countries where rapid urbanisation largely owing to migration from rural to urban areas threatens the stability of existing infrastructure, housing and its support services. Hussaini et al., (2019) note that Africa is the fastest urbanising continent and that urbanisation in Sub Saharan Africa is characterised by the influx of poor people into urban areas. Urbanet (2018) asserts that the urban population "has been experiencing a rapid rise since 2010 and is expected to grow from 60 million to almost 300 million inhabitants in Nigerian cities".

The report confirms that as at 2018, forty of Nigeria's cities have a population between 300,000 and 1 million inhabitants. Out of these, nine medium-sized cities are home to between 1 and 5 million residents with Lagos accommodating more than 10 million people.

These statistics invariably affect housing and its support infrastructure as urbanisation is closely linked to problems of planning, inadequate provision of housing, basic infrastructure and amenities (Eziyi Offia Ibem & Aduwo, 2013; Morakinyo et al., 2014; Zaki, Y.M. et al., 2015). The lack of such vital infrastructure produces slums proliferating many urban areas in Nigeria. To minimise pressure on existing facilities and ensure that the quality of existing housing stock is not compromised, urban and housing experts need to consider pertinent issues in the design of new housing schemes, notably the provision of basic urban services that meet specific requirements of residents (Equere et al., 2020).

To this end, several studies assess the adequacy of existing housing environments holistically using satisfaction ratings from residents (Adegbile et al., 2020; Babalola et al., 2019; Eziyi Offia Ibem, 2013; Omolabi, 2018; Wakuma Kitila, 2019). Etminani-Ghasrodashti et al. (2017) however observe that most studies focus on physical attributes of housing units as influential factors determining overall residential satisfaction. Such attributes include level of thermal/visual comfort, size of living/sleeping areas, noise and privacy, light, ventilation, sizes of housing units as well as housing services (Eziyi O. Ibem & Amole, 2013; Eziyi Offia Ibem & Aduwo, 2013; Eziyi Offia Ibem & Alagbe, 2015). All of the aforementioned studies were conducted in Southern parts of Nigeria, with little comparative investigations conducted in Northern regions. It is often unclear which attributes of dwelling units and their support infrastructure are most critical in terms of satisfaction and adequacy from the perspective of end users in Northern Nigeria.

Investigating satisfaction and adequacy of dwelling unit attributes and supporting infrastructure is important for several reasons. First, the Nigerian government invests a large proportion of funds in housing. This trend projects into the near future as the Federal Government (FG) proposes to construct about 300,000 housing units across the nation as part of its COVID-19 palliative strategies (Nigerian Investment Promotion Comission, 2020). Secondly, the impact of direct modifications by individual residents in adapting to lifestyle changes are largely made at the micro level of dwellings, separate from communal efforts at neighbourhood level. Initiation of pressure on urban infrastructure and support often commences at dwelling unit level, thus making it worthy of study. Thirdly, design decisions of planned estates culminate at dwelling units but information regarding ways residents perceive adequacy through satisfaction ratings of attributes and support infrastructure at this level are rare. This is critical to inform and guide design even from inception where critical decisions are often made based on assumptions made by professionals' experience and intuition (Aragonés et al., 2017). Such decisions are often not approved by the residents, a reason proffered for the failure of many housing programs.

This study assesses satisfaction with dwelling unit attributes and support infrastructure to establish ways residents perceive adequacy of their housing at micro levels. This is to inform design and policy towards improvement of future projects and creation of more sustainable and resilient built environments in light of the challenges posed by urbanisation in Nigeria.

2. LITERATURE REVIEW

2.1. Residential Satisfaction and Adequacy in Housing

Residential satisfaction as a multidimensional construct measuring the extent people are happy with their housing environment and associated services (Eziyi Offia Ibem & Aduwo, 2013). The concept is often employed as a measure of housing quality and adequacy (Eziyi Offia Ibem

& Alagbe, 2015). Two theoretical approaches frequently applied in residential satisfaction studies are Aspiration Gap (Galster, 1987) and Housing Adjustment theory (Morris & Winter, 1975).

Aspirations Gap Approach posits that satisfaction depends on an individual's cognitive construct, a reference condition for salient features of housing environments depending on self-assessed needs and aspirations. "If the current situation is perceived to be in proximate congruence with the reference situation, an affective state of satisfaction should be manifested" (Galster, 1987). If present housing situations fail to meet this reference point, a family adapts by redefining its needs, altering the evaluation of current residential situation or by lowering its standards in order to reconcile aspirations and actual situations. The second alternative is for the family to manifest dissatisfaction with the current housing situation. Closely related to Aspirations Gap Approach is Housing Adjustment Theory, which posits that residents evaluate housing situations based on family and societal norms. "If the housing does not fit with normatively derived needs, a housing deficit is said to exist" (Morris & Winter, 1975). This is likely to produce dissatisfaction. Morris and Winter (1975) assert that dissatisfied residents are likely to relocate to another house (residential mobility), change the family size or composition (family adaptation) or transform the house through adaptation, modification or alteration.

Several studies evaluate satisfaction with housing attributes and supporting urban infrastructure in Nigeria (Table 1) with the literature revealing four trends. First, satisfaction with housing attributes is a function of the quality of design and construction. Jiboye (2012) post-occupancy evaluation of housing units in Lagos reported that residential satisfaction was a function of the total physical characteristics of housing units. The initial high quality of construction as well as maintenance carried out by residents of the estate were reasons proffered in support of the findings. Good maintenance culture was associated to the high socio-economic status and educational attainments of residents (A. Oladapo, 2006). Consequently, residents were generally satisfied with the housing situation in the estate as were similar cases in Maiduguri (Mammadi et al., 2020), Ogun State (Adegbile et al., 2019) and Zaria (Maina et al., 2018). These results however contrast with findings submitted by Ukoha and Beamish (1997) Abuja were residents were dissatisfied with housing characteristics. This was largely because "structure types determine the availability of building features in dwelling units" (p. 458), resulting in dissatisfaction as features of the dwellings described in Table 1 failed to meet expectations of residents. Reports of dissatisfaction with dwelling unit features and support services also occurred in Lagos (Omolabi, 2018), Ibadan (Morakinyo et al., 2014) as well as in Osogbo (R. A. Oladapo & Adebayo, 2014).

The second trend in literature suggests that adequacy of urban infrastructure depends on multiple factors, key among them being the quality of original construction, management and maintenance of said infrastructure. Oluwunmi et al. (2012) observed that residents were satisfied with housing support services and infrastructure at Covenant University largely due to huge investments by the institution in a bid to ensure maintenance of optimum services of diesel-powered generating sets to supplement epileptic public power supply as well as forty boreholes to augment water supply. Professional security operatives provide adequate surveillance cover to residents within the school's premises. Generally, dissatisfaction with support services was common in public estates compared to private estates in literature.

Thirdly, infrastructure directly supporting dwellings notably water supply, electricity supply and waste disposal were common areas of dissatisfaction especially among residents of public estates. Notable exceptions to these cases were findings by Adzande (2013) as well as Ukoha and Beamish (1997), the latter reporting highest satisfaction with water pressure from Table 1.

Table 1 Studies on satisfaction with dwelling unit attributes and infrastructure in Nigeria

Author(s)	Purpose	Key findings
Mammadi et al. (2020)	To assess residents' satisfaction with public housing in Maiduguri	Residents were very satisfied with components of public housing. Satisfaction was high with condition of bedrooms, living rooms, stores, kitchen, roof, finishes, toilets and dining areas
Adegbile et al. (2019)	To investigate influence of housing attributes on housing satisfaction in selected residential areas in Ogun State	Residents were satisfied with space adequacy, sizes of rooms and building materials. More than 50% of residents were satisfied with dwelling unit attributes.
Omolabi (2018)	To investigate housing quality and prospects for neighbourhood revitalisation in public low-income housing estates in Lagos	Residents were generally dissatisfied with housing design, sizes of living rooms and bedrooms, baths, roofs, exterior finishes/paint, ventilation, illumination, water and electricity supply, waste disposal, noise and sewage disposal. Residents were satisfied with toilets, kitchens, ceilings, walls and floors, rent and mortgage
Maina et al. (2018)	To investigate satisfaction of residents with staff housing at Ahmadu Bello University Zaria	Residents were most satisfied with housing attributes notably sizes of living and functional spaces, open areas/landscaping, lighting, air quality. Dissatisfaction was highest with water and power supply, waste management and sewage disposal
Fakere et al. (2018)	To examine performance of infrastructural facilities in Akure	Residents found infrastructural facilities unsatisfactory. Satisfaction was highest with waste management and least with water supply
Zaki et al. (2015)	To assess environmental conditions and conformity to housing standards within new settlements in Kaduna State	Low ranking of water supply implies inadequacy. Non-compliance to plot coverage standards resulted in congestion of surveyed areas
Morakinyo et al. (2014)	To evaluate housing infrastructural provision in Bashorun housing scheme, Ibadan	Dissatisfaction with household facilities, inadequate and poor water supply largely from wells; poor waste disposal, unstable power supply.
Oladapo & Adebayo (2014)	To examine effects of facilities on residents' satisfaction in Osogbo	Residents in Isale Ogun were dissatisfied with water, electricity supply, toilets and refuse. Residents of Alekuwodo were satisfied with most facilities except refuse disposal
Ibem & Aduwo (2013)	To examine accessibility of services and facilities for urban residents in newly constructed public housing in Ogun State	Residents had poor access to treated water, inadequate power supply
Adzande (2013)	To assess condition, residents' satisfaction and role of agencies in the provision of infrastructure in Nyiman layout, Makurdi	Assessment for development at street level was low implying inadequate provision of physical infrastructure. Residents were dissatisfied with refuse disposal but satisfied with water, electricity supply and sewage disposal
Oluwunmi et al. (2012)	To investigate user satisfaction with residential facilities at Covenant University, Ota	Residents were satisfied with electricity and water supply, security, lawn/flower maintenance, sanitation and waste disposal systems. Dissatisfaction occurred with fumigation service, maintenance and internet connectivity
Ukoha & Beamish (1997)	To examine residents' satisfaction with public housing in Abuja	Dissatisfaction with smaller typologies and most building features owing to poor construction (plumbing, lighting, doors, interior/exterior painting, sizes and number of rooms, study, storage and privacy). Satisfaction was highest with water pressure

Lastly, few studies investigate satisfaction with dwelling unit attributes and support

infrastructure only. Majority of studies on residential satisfaction in Nigeria investigate dwelling unit features as part of the larger system of housing environments based on the Housing Habitability Framework, made up of four subsystems-tenant, dwelling, environment and management illustrated in Figure 1.
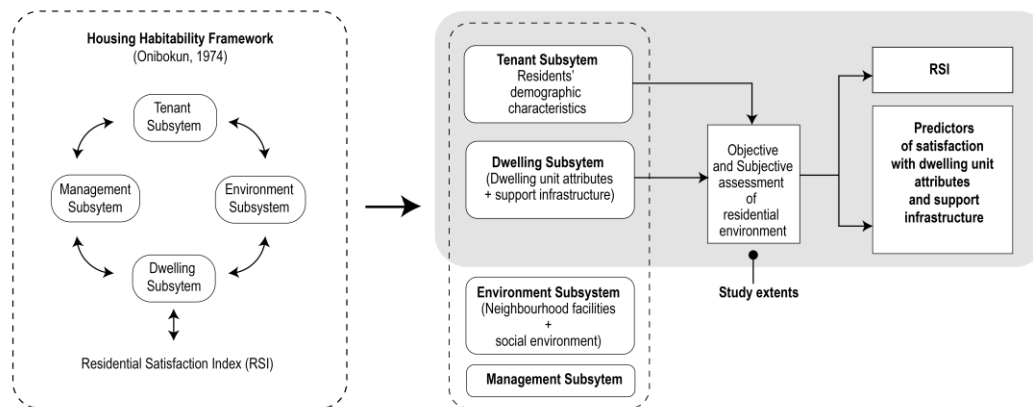
Figure 1 Conceptual framework of the study

This study investigates residents' satisfaction with dwelling units and supporting infrastructure via two research questions. First, which aspects of the dwelling subsystem are satisfactory or adequate and which aspects are not? Second, how do residents perceive the dwelling subsystem in terms of satisfaction ratings to guide future planning of similar estates in the study area?

3.   METHODOLOGY

3.1. Study Area

Northern Nigeria comprises three geopolitical zones (Figure 2) covering an area of approximately 660,000 km^2 of the country's total land mass of 923, 768 km^2 (World Bank, 2020). Two estates, in Dutse and Sokoto were selected in the Northwest region, while another two in Potiskum and Gombe represent the Northeast region. An estate was selected in Abuja representing the Northcentral region. Criterion for selection was that estates were procured and constructed using public funds and later allocated to civil servants on owner-occupier basis.

The estate in Dutse contains 2, 3 and 4-bedroom bungalows, while 2 and 3 bedroom bungalows make up the Sokoto sample. Similarly, the estate in Gombe comprises 2 and 3 bedroom bungalows, the former designed as semi-detached units while the latter are stand-alone bungalows. The estate in Potiskum contained the least population of 50 units consisting of 2 and 3 bedroom bungalows. In Abuja, dwellings were designed as 2 bedroom semi-detached bungalows. All dwelling units contain an open courtyard to accommodate diurnal activities of residents in the hot-dry savanna climate common across Northern Nigeria.

Sample size (n) was calculated as a ratio of total population (N) and $1+N(e^2)$ where e represents 0.05 margin of error (Bixley & Yamane, 1965). This produced an overall sample size of approximately 280, with samples for individual estates computed pro-rata (Table 2). We encountered tremendous problems during the survey in estates located in the Northwest region particularly Sokoto due to high levels of insecurity and banditry across the region at the time of the study in 2019 (Lar, 2019).

Figure 2 Location of Study areas

Sociocultural and religious restrictions further compounded the situation (Maina et al., 2018). With the aid of locally sourced field assistants, 235 questionnaires were eventually distributed. Respondents granted their consent prior to the survey. Overall, 125 questionnaires (45% of the sample size) were retrieved and found valid for analyses. This was above the minimum 30% acceptable return rate expected for construction related research (A. Oladapo, 2006).

Table 2 Population and sample size

Location of Estate	Population (N)	Sample	Distributed	Valid
Gombe	115	35	55	35
Potiskum	50	17	50	23
Dutse	200	60	50	27
Sokoto	500	150	50	23
Abuja	60	18	30	17
Total	925	280	235	125

3.2. Dataset and Analyses

The research employed a questionnaire survey to address the study aim. Adapted from Ibem et al. (2017), the questionnaire contained three sections. Section A comprises ten socio-demographic variables describing the tenant subsystem. These include gender, marital status, age, education, income, employment sector, length of stay, household size, number of bedrooms and tenure status. These were analysed using descriptive statistics and presented in Table 3. Section B requested data on predominant sources of dwelling support infrastructure namely water supply, electricity supply and waste disposal. These were analysed using simple counts and percentages, with results presented in Figures 3-5 respectively. Section C contained 15 variables describing the dwelling subsystem comprising variables in Table 4. Rent/cost of acquiring a house was included in the list because affordability is a serious concern for sustainability of housing and support infrastructure (Durodola et al., 2016). Data from this section was analysed in two ways to address research questions posed by the study.

To address the first question, data in form of satisfaction ratings from respondents were analysed for relative satisfaction index (RSI) calculated for each variable as a ratio of the sum of actual Satisfaction Scores (SS_{ac}) and maximum possible Satisfaction Score (PSS_{max}) on a 5 point likert scale from 1 (very dissatisfied, VD) to 5 (very satisfied, VS) in Equation 1. For 125 questionnaires, PSS_{max} equals 625.

$$RSI = \frac{\Sigma SS_{ac}}{PSS_{max}}$$

(1)

A variable was considered satisfactory (and adequate) if its RSI was above 0.6 (Ogu, 2002). RSI scores below this value were dissatisfactory and therefore inadequate (Table 4). Data from this section also produced mean Dwelling Unit Satisfaction Scores (DUSS) for each respondent and for the entire sample. The overall cut-off point was set at 3.0, this value being the mid-point of a 5-point likert scale. These were instrumental in addressing research question two via two sets of analyses.

First, Principal Components Analysis (PCA) with Varimax rotation reduced the 15 dwelling unit variables into three components. These represent viewpoints of residents with dwelling unit attributes and support infrastructure in terms of satisfaction and adequacy ratings (Table 5). Kaiser-Meyer-Olkin measure of sampling adequacy was 0.789, above the minimum expected value of 0.5 (Field, 2013). Secondly, CATREG regression was employed to establish predictors of satisfaction with DUSS from both tenant and dwelling subsystem variables (Table 6). CATREG analysis was employed in this study because it is suitable for analyses of nominal, ordinal and numerical data in small samples compared to other general linear regression models (Eziyi Offia Ibem & Alagbe, 2015). The next section presents results from all of these procedures.

4.　RESULTS AND DISCUSSION

4.1. Demographic Profile of Respondents

Results from Section A of the questionnaire revealed that larger proportions of respondents were male (82, 66%), married (89, 71%), aged 31-60 years (87, 70%), tertiary degree holders (78, 62%) and mid-income earners (54, 43%). Respondents were also largely employed in the public sector (70, 56%), resident for 1-5 years in the estates (57, 46%) and accommodate household sizes of 1-4 persons (52, 42%) within 3 bedroom houses (53, 43%). Three-quarters of the sample (93, 75%) also own their dwellings. These statistics imply that respondents are qualified to provide the required information being familiar with the housing environment. Demographic data also fit the expected profiles of household heads living within public housing estates in Nigeria from literature (Eziyi Offia Ibem & Alagbe, 2015).

Table 3 Demographic profile of respondents

Variable	Frequency (n 125)	%
Gender		
Male	82	66%
Female	31	25%
No response	12	9%
Marital status		
Married	89	71%
Single	22	18%
No response	14	11%
Age in years		
Up to 18	3	2%
18-30	33	26%
31-60	87	70%
60+	2	2%
Educational qualification		
O'Levels	20	16%

Diploma	21	17%
Degree	78	62%
No response	6	5%
Monthly income in Naira		
Less than 18,000	15	12%
18-50,000	30	24%
51-150,000	54	43%
150,000+	17	14%
No response	9	7%
Employment		
Public sector	70	56%
Private sector	45	36%
Retiree	6	5%
No response	4	3%
Length of stay		
Less than 1 year	19	15%
1-5 years	57	46%
6-10 years	21	17%
10 +	26	21%
No response	2	1%
Household size		
1-4 persons	52	42%
5-6 persons	36	29%
6+	35	28%
No response	2	1%
Number of bedrooms		
2	48	38%
3	53	43%
4	17	14%
Above 4	3	2%
No response	4	3%
Tenure		
Owner-occupier	93	75%
Renter	30	24%
No response	2	1%

Information from Section B illustrates that boreholes present the most predominant source of water supply accounting for 35% (n 44) of responses in Figure 3. These are followed by vendors (38, 30%), wells (21, 17%) and lastly, pipe-borne public water supply (18, 14%). These figures support Fakere et al. (2018) who submit that public water supply in many Nigerian urban areas is inaccessible and unreliable, largely dependent on self-help alternatives by residents.
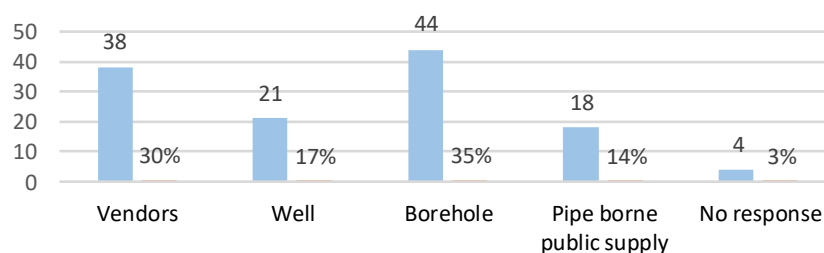
Figure 3 Predominant source of water supply

In contrast, data from Figure 4 illustrates that public power supply is the most predominant source of electricity supply across the regions, accounting for 48% (n 60) of responses. Supply from solar panels (45, 36%) follow. Generating sets (18, 14%) record the lowest frequencies from the sample. This reveals a marked improvement in public power supply in recent times as generating sets were the predominant source of electric power supply for many residents in Nigeria according to Stanley et al. (2016).
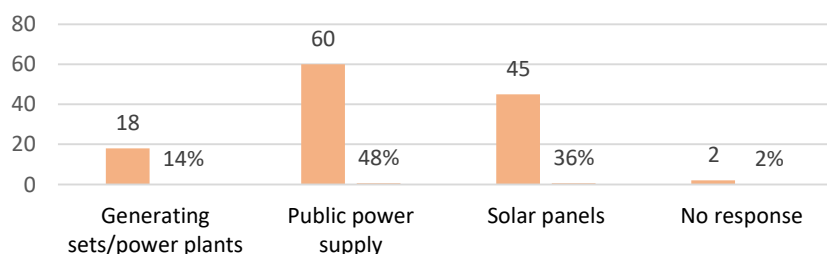
Figure 4 Predominant source of electricity/power supply

Figure 5 illustrates that contractors (57, 46%) are largely responsible for disposing waste across the sample. A sizeable proportion of residents (41, 33%) however dispose their own waste. Estate managers as well as government agents (8, 6% each) record lower figures for responsibility of waste disposal.
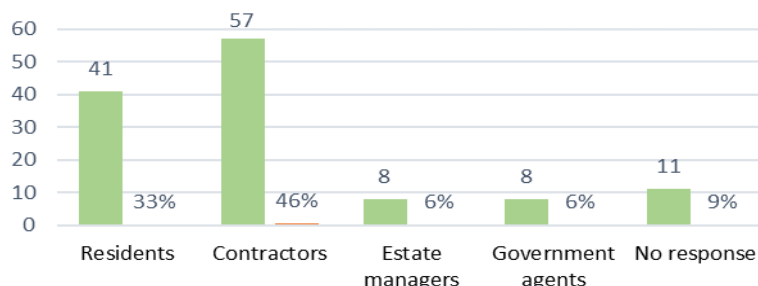
Figure 5 Responsibility for waste disposal

Overall, objective statistics from dwelling unit support services and infrastructure reveal that water supply is a common problem across the sample. This is unlike electricity supplied through public power lines, although results on the latter suggests that solar panels supplement power supply across the sample (Figure 4). This is a commendable trend towards sustainability and use of alternative energy sources. Nonetheless, results imply that basic support services and infrastructure notably water and to some extent, power supply depend largely on personal efforts made by residents. In the case of water supply, boreholes and wells predominate the sample. Results reveal that the situation may be better in the case of waste disposal (Figure 5) with evidence of organised formal waste disposal avenues in the form of contractors. Visual observations during the survey however revealed that residents employed pockets of open areas to dispose household waste with attendant health risks to communities within the estates.

4.2. Satisfaction with Dwelling Unit Attributes and Infrastructure

In response to research question one, nine variables recorded RSI values above 0.6. Presented in Table 4, the first seven variables relate to design and planning attributes of dwelling units. These include natural lighting and ventilation, location of the house, levels of noise and privacy, sizes of bedrooms, external appearance of the house as well as the typology, largely based on the number of bedrooms in the house. The other two variables are electricity supply and affordability issues in form of rent/cost of acquiring the house. These findings contrast to

results submitted by Salisu et al. (2019) where residents of public housing in Lagos were most dissatisfied with the physical aspects of their dwelling units, underscoring the observation that residential satisfaction is contextual.

Table 4 Descriptive for dwelling unit attributes and infrastructure

Dwelling unit attribute/infrastructure	VD 1	D 2	N 3	S 4	VS 5	SS_{ac}	Mean	SD	RSI
Natural lighting/ventilation	9	15	37	37	27	433	3.46	1.168	0.693
Location of the house	6	17	44	32	26	430	3.44	1.110	0.688
Noise levels in house/estate	9	17	37	35	27	429	3.43	1.180	0.686
Privacy	13	19	32	32	29	420	3.36	1.279	0.672
Size of bedrooms	6	26	36	43	14	408	3.26	1.064	0.653
External appearance of the house	7	23	45	35	15	403	3.22	1.062	0.645
Housing typology	12	20	45	27	21	400	3.20	1.185	0.640
Electricity/power supply	16	20	37	32	20	395	3.16	1.247	0.632
Rent/cost of acquiring the house	11	28	43	26	17	385	3.08	1.154	0.616
Bath/toilet facilities	13	32	39	28	13	371	2.97	1.150	0.594
Sizes of living/dining spaces	21	24	39	22	19	369	2.95	1.288	0.590
Type of building materials	13	35	35	30	12	368	2.94	1.152	0.589
Number of bedrooms	10	40	38	24	13	365	2.92	1.119	0.584
Sizes of cooking/storage spaces	16	36	38	25	10	352	2.82	1.139	0.563
Water supply/sanitary service	25	38	31	14	17	335	2.68	1.293	0.536

Dissatisfactory aspects of dwelling units with RSI values less than 0.6 relate to inadequate service and living areas notably baths, toilets, cooking and storage spaces, number of bedrooms, quality of construction materials and lastly, water supply and sanitary services (Table 4). Pertinent to this discussion is the observation that all dissatisfactory functional spaces outlined above (except number of bedrooms and sizes of living spaces) accommodate diurnal tasks that are heavily dependent on supply of water to dwelling units. This observation underscores the pervading impact of water supply on satisfaction with dwelling units, confirming results presented in the preceding section regarding the inadequacy of this essential support service in the study area. It also furnishes further proof that satisfaction ratings in housing environments directly reflect adequacy and that one concept can be substituted for the other (Ibem et al., 2015).
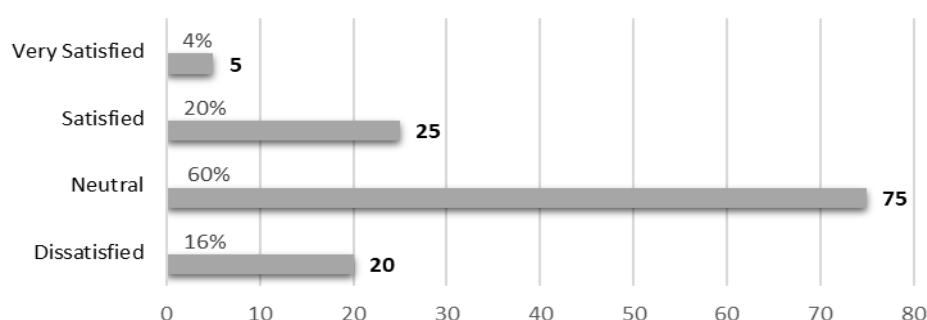

Figure 6 DUSS for dwelling unit attributes and infrastructure

Overall, DUSS of 3.13 (SD 0.69) suggests that residents were satisfied with their dwelling unit and support infrastructure. This result, reflected in Figure 6, illustrates that 84% of respondents recorded DUSS values of 3.0 (neutral) and above. There were no very dissatisfied residents.

4.3 Dimensions and Predictors of Satisfaction with Dwelling Unit Attributes and Infrastructure

4.3.1 Dimensions of satisfaction with dwelling unit attributes and infrastructure

Results from PCA revealed three underlying components reflecting viewpoints of residents on satisfaction with dwelling unit attributes and infrastructure in the study area. In line with findings presented in Table 4, the first component describes housing design and cost, explaining over half (25.34%) of the total variance in Table 5. All items extracted for this component relate to aspects of dwelling unit design and planning, except rent and cost of acquiring the house. Ige and Evelyn (2018) present similar findings in their study of a Public Private Partnership estate in Akure, Southwest Nigeria where construction and design of dwelling units explained 65.55% variance of residential satisfaction scores.

Table 5 PCA of satisfaction with dwelling unit attributes and infrastructure

Factor/component	Factor loading	Eigen value	% variance	% cum.
#1 Housing design and cost (α=0.846, M 3.10, SD 0.781)		3.80	25.34	25.34
Size of bedrooms	0.779			
External appearance of the house	0.726			
Sizes of living/dining spaces	0.694			
Type of building materials	0.674			
Number of bedrooms	0.648			
Rent/cost of acquiring the house	0.581			
Housing typology	0.547			
Location of the house	0.466			
#2 Housing services and environmental conditions (α=0.762, M 3.06, SD 0.864)		2.71	18.07	43.41
Natural lighting/ventilation	0.795			
Privacy	0.695			
Water supply/sanitary services	0.665			
Sizes of cooking/storage spaces	0.556			
Bath/toilet facilities	0.493			
#3 Electricity supply and noise levels (α=0.544, M 3.30, SD 1.0)		1.66	11.10	54.50
Electricity/power supply	0.777			
Noise levels	0.767			

The second component describes service spaces as well as indoor environmental quality (IEQ) conditions and explain about 18% of the total variance in Table 5. Residents clustered natural lighting, ventilation and privacy together with service-zone functions specifically water supply and sanitary services, cooking and storage spaces and finally, bath and toilet facilities. Interestingly, the third component clusters electricity supply with noise levels, two variables closely related to power generation in the past few years (Stanley, 2016). Because many residents depended on generating sets for power, high levels of disturbance were associated with noise from generators. The low reliability value of 0.544 and high SD for this component (1.0) suggests that variations exist across the sample and imply that ratings for both electricity supply and noise levels differ remarkably across the different estates surveyed, in spite of both variables recording relatively high factor loadings in Table 5. This however component records

the highest mean value of 3.30. Future studies at estate levels with larger samples will help in verifying this finding. Notwithstanding, the fact that electricity is clustered with noise suggests continued use of generators and that power supply remains an issue among residents of public housing estates in Northern Nigeria. Inadequate support services and infrastructure fosters dissatisfaction as illustrated in Table 4.

In sum, PCA reveals that residents view adequacy with dwelling unit attributes and infrastructure in terms of design and cost, service functions and environmental conditions as well as electricity supply and noise levels. This categorisation provides design and policy makers guidelines for planning future housing projects in the study area.

4.3.2 Predictors of satisfaction with dwelling unit attributes and infrastructure

CATREG regression established that the three components from the PCA significantly predict satisfaction with dwelling unit attributes and infrastructure as shown in Table 6. A combination of extracted components and tenant demographic variables significantly predict satisfaction with dwelling unit attributes and infrastructure with F (20.54, 18), p = *0.000*. The R^2 value (0.777) indicates that the regression model explains 77.7% of the variance in satisfaction with dwelling subsystem variables.

Table 6 Predictors of satisfaction with dwelling unit attributes and infrastructure

Variables	Standardized Coefficients		df	F	Sig.
	Beta	Bootstrap (1000) Estimate of SE			
#1 Housing design and cost	.541	.055	1	97.102	.000
#2 Housing services and environmental conditions	.362	.055	1	42.550	.000
#3 Electricity supply and noise levels	.198	.052	1	14.450	.000
Number of bedrooms	.076	.048	3	2.521	.062
Employment	.065	.039	2	2.699	.072
Gender	.070	.049	1	2.051	.155
Tenure type	.054	.043	1	1.563	.214
Monthly income	.055	.046	2	1.425	.245
Age	.042	.041	2	1.048	.354
Number of persons in household	.034	.044	1	.611	.436
Highest education	.013	.032	1	.164	.687
Marital status	-.016	.053	1	.088	.767
Length of stay	-.047	.058	1	.656	.420

Dependent variable: DUSS

Results from Table 6 reveal that number of bedrooms as well as employment both approach but fail to achieve significance at p<0.05 across data from the five public housing estates surveyed. This result suggests that among objective characteristics of dwelling units, the number of bedrooms in a dwelling unit is crucial to residential satisfaction in the Nigerian context as submitted by Ukoha and Beamish (1997). Future studies at estate levels would be beneficial in clarifying this finding. The result on employment confirms that residents in public service are more satisfied with their dwellings and support infrastructure than their counterparts in the private sector. Ibem and Aduwo (2013) echoing Elsinga and Heoskstra (2005) note that home ownership, the policy of owner-occupancy in our study being a prime example, is a significant predictor of residential satisfaction.

While eight of the variables in the tenant subsystem record positive beta values, marital status and length of stay recorded negative beta values (Table 6). This implies that married respondents as well as those who have lived for longer periods within the estates tend to be dissatisfied with their dwellings. Married respondents are likely to have more responsibilities such as raising a family and are thus more likely to remain in a home for longer periods compared to single respondents unencumbered by family obligations. This in turn is likely to produce dissatisfaction over time especially for married respondents with changing family needs occupying inflexible dwelling units.

5. CONCLUSION

This study explored residents' satisfaction with dwelling units and supporting infrastructure in five selected estates across Northern Nigeria as such studies are rare in literature. The investigation assessed adequacy of dwelling units and services as well as residents' perception of the same variables to inform future housing developments in the region. Conclusions are summarised in four points. First, support services, especially water supply are grossly inadequate. Although electricity supply has improved, water supply and waste disposal leave enormous room for acute intervention by government and civic society. Second, satisfaction was highest with design related attributes notably natural lighting and ventilation, location of the house as well as noise, privacy, size of bedrooms, appearance, typology, electricity supply and cost of housing. Satisfaction was lowest with service and living areas notably baths, toilets, cooking and storage spaces, number of bedrooms, quality of construction materials and lastly, water supply and sanitary services. Third, residents perceive satisfaction with dwelling unit attributes and infrastructure in terms of design and cost, services and IEQ as well as electricity supply and noise levels. Lastly, factors influencing ways residents perceive their dwelling unit attributes and infrastructure significantly predict satisfaction within the estates.

Recommendations from the study target design, planning and policy-making. User perspectives ought to guide design of future projects. Attention to living areas, bedrooms, appearance of dwellings, materials for construction and cost is essential, as these were the most pertinent attributes of dwelling units influencing satisfaction from user perspectives. IEQ variables such as natural lighting and ventilation benefit from careful zoning of service functions as illustrated from the study findings. Additionally, the deplorable state of water supply requires support from Non-Governmental Organisations as well as self-help initiatives. The latter is more common in Southern regions of the country. However, specific policies supporting such initiatives are overdue for implementation in Northern regions of Nigeria. Finally, the finding that solar energy is now an alternative source of electricity supply at dwelling unit level ought to be supported by policies whereby dwellings are designed to generate power thus reducing the pressure on public power supply. This is especially pertinent across a region with enormous supplies of natural daylight all year round.

As indicated within the methodology, this study was not devoid of limitations. First, this was a cross-sectional survey of residents' perceptions across several disparate estates in Northern Nigeria. Longitudinal surveys across the region will proffer more robust, stable and generalisable results. Secondly, future studies would benefit from in-depth investigations of individual estates, as residential satisfaction is contextual. While results from this explorative survey provides an overview of the situation across the region, policy makers will benefit more from micro rather than macro level analyses. Finally, sustainability and resilience are largely studied within social and neighbourhood environments. Similar analyses at neighbourhood levels in the region would enrich our understanding satisfaction and adequacy of housing environments and support infrastructure.

6. ACKNOWLEDGEMENT

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COMPRESSIVE STRENGTH CHARACTERISTICS OF CONCRETE MODIFIED WITH TREATED HIGH-DENSITY POLYETHYLENE

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ABSTRACT

Waste plastic materials are typical wastes of interest to researchers and are arguably the most common forms of waste, especially in African cities. The reuse of plastic waste in concrete matrices has the potentials to contribute to the development of sustainable concrete likely to conserve resources and prevent pollution. However, the inclusion of plastics in concrete has been reported to have a negative impact on its compressive strength behaviour. This research is aimed at ameliorating this negative impact through pulverisation and chemical treatment of High-Density Polyethylene (HDPE) before its use as an admixture for concrete production. Concretes of Grades M25 and M50 were prepared using (150 x150 x 150) mm steel moulds, adopting the BRE mix design method. The concrete mix was modified with pulverised High-Density Polyethylene (HDPE) treated with 20% hydrogen peroxide at (0, 0.25, 0.5, 0.75, and 1%) by weight of cement. Hydroplast-500, a superplasticizer was used throughout the study in order of 1000litres/50kg by weight of cement. A constant water/cement ratio of 0.4 and 0.36 was adopted for requisite workability for Grades M25 and M50 concretes respectively. After 7, 28, and 90 days of curing in water, the concrete cubes were dried and tested for their compressive strengths. Results obtained showed that at HDPE content beyond 0.5%, restrained hydration takes negative effects on the concrete. It was also shown that the designed compressive strengths of the tested samples were satisfactorily met in all cases indicating improvement in the compressive behaviour of the samples. Based on the findings of this study, it was recommended that treated pulverised HDPE could be used as an admixture in concretes without compromising their compressive strengths.

Keywords: Chemical Treatment; Compressive Strength; High-Density Polyethylene; Modified Concrete; Pulverisation.

1. INTRODUCTION

It is universally acknowledged that concrete is the most widely and conventionally used construction material worldwide as a result of its versatility, strength, durability, ease of use, and contribution to social progress, economic growth, and environmental protection (Paul, 2016; The Guardian, 2019). The extensive usage of concrete in construction according to Lafarge Holcim (2019) justifies why this conventional material is being continuously modified and developed to perform better in many situations.

According to Rutkowska et al. (2020), concrete has proven to be excellent disposal means for fly ash, silica fume, ground granulated blast furnace slag, and marble powder which can trap hazardous materials and also enhance the properties of concrete. Interestingly, the global construction industry consumes an estimated 20 billion tons of concrete every year and this large annual production of concrete consequently leads to an equally large estimated consumption of component materials of about 15 billion tons of aggregates and 4.2 billion tons of cement (Tosic et al., 2017). Taking into account the huge volume of concrete produced annually, the concrete industry is unquestionably one of the ideal mediums for the economic and safe use of millions of post-consumer waste plastics (Sandanayake et al., 2020).

Currently, global plastic production exceeded 311 million metric tons from 2.5 billion metric tons of solid waste generated in 192 countries (Bokani, 2019). A separate study by Statista (2021) revealed an estimated global plastic production of 368 million metric tons per year. In Nigeria for instance, the per capita consumption of plastics has grown by about 5% annually over the past ten years, from 4.0 kg in 2007 to 6.5 kg in 2017, and is estimated to be 7.5 kg in 2020 (Bokani, 2019). This fast growth is attributed to the boost in industrialization and the rapid improvement in standards of living (Babafemi et al., 2018). Averill and Eldredge (2016) further adduced reasons for the phenomenal increase in the usage of plastics to its low density, strength, user-friendly designs, fabrication capabilities, lightweight, long life, and low cost. Therefore, plastic materials are typical waste materials of interest and are arguably the most common forms of waste in African cities (Smallstarter, n.d.).

Polyethylene according to Statista (2021) is the world's biggest and most popular tonnage plastic prepared by the catalytic polymerization of ethylene. High-Density Polyethylene (HDPE) which is defined by the density of greater or equal to 0.941g/cm^3 accounts for 46% of total polyethylene production globally (Plasticsinsight.com, n.d.). High-Density Polyethylene possesses special properties such as increased resistance to permeability, good chemical resistance, high rigidity, high toughness and flexibility, improved heat resistance, good impact resistance, and lightweight which makes it a material of choice for many engineering applications (Dorigato et al., 2012; Plasticsinsight.com, n.d.).

Pulverised HDPE may be defined as plastics of HDPE parent materials that have been reclaimed, sorted, and reduced to smaller particles by grinding to create a new material with smaller particle sizes and improved surface area (Plasticsinsight.com, n.d.). Therefore, pulverised high-density polyethylene concrete is a composite material consisting of a cement-based matrix with ordered or randomly distributed particles of high-density polyethylene material as admixtures.

The compressive strength of concrete generally is its ability to resist compressive forces which is a force tending to compress or squeeze it together. The compressive strength of concrete is one of the most considered quantitative parameters because of its requirement when designing structural concrete elements (Slaiai, 2017).

A study by Naik, et al. (1996) has investigated the effects of post-consumer plastics in concrete and found that the inclusion of plastic fibers in concrete increases its ductility while improving fracture resistance, though with a negative impact on compressive strength and creep behaviour. This phenomenon according to the authors is because ordinary Portland cement concrete reinforced with plastics is liable to poor bonding due to the lack of chemical bond that exists between the materials. Studies by Lu et al. (1998) and Ebnesajjad (2011) have suggested that poor bonding between concrete and plastic materials may be improved by physical processing or chemical treatment of plastics prior to mixing. These techniques, according to these studies, have a good promise of improved bonding of plastics to cementitious materials as a result of bonding likely to develop with the surrounding matrix, which may result in higher strength. In

light of all these arguments, this research is premised on ameliorating the negative impact of poor bonding between plastic based materials and concrete by pulverisation and chemical treating of High-Density Polyethylene (HDPE) before its use as an admixture for concrete production.

2. LITERATURE REVIEW

The compressive strength of concrete generally is its ability to resist compressive forces which is a force tending to compress or squeeze it together. The compressive strength of concrete is one of the most considered quantitative parameters because of its requirement when designing structural concrete elements (Slaiai, 2017). The compressive strength of plastic concretes depend on many parameters such as the water/cement ratio, constitution level of the plastic materials (mostly aggregates), and the type and shape of the waste plastic (Akçaözoğlu et al., 2010; Albano et al., 2009; Asokan et al., 2009; Babafemi et al., 2018). The mechanical properties of concrete containing recycled PET were identified by Cordoba et al. (2013) to depend on the particle size with the highest compressive strength obtained with the smallest sizes of PET (0.5mm). The study also established the fact that mechanical properties of plastic concrete such as compressive strength increases with a reduced particle size of plastics and with lower concentrations of the plastic content. The lower sizes and concentrations of plastic particles create fewer spaces in the concrete, and in consequence, strength is increased (Ávila Córdoba et al., 2013). The compressive strength of plastic shreds in concrete was studied by Naik, et al. (1996). The study reported a compressive strength decrease with an increase in the amount of plastic in concrete, particularly above 0.5% plastic addition.

Patil et al. (2014) reported that the modified concrete mix, with the addition of plastic aggregate replacing conventional aggregate up to a certain 20% gives strength within the permissible limit but decreased compressive strength when plastic was replaced with coarse aggregate. Besides, Raghatate and Polytechnic (2012) reported that there is about a 20% reduction in compressive strength at 28 days of curing using the plastic pieces in concrete. In each case reported, compressive strength reduction was a result of improper bonding between organic plastic materials and inorganic cementitious materials.

Gu and Ozbakkaloglu (2016), attributed the reduction in compressive strength to one or a combination of the following: the elastic modulus of the plastic aggregates/filler aggregates being lower than the natural concrete aggregate, the low bond strength between the surface of the plastic aggregate/filler and the cement paste, the restrained cement hydration reaction near the surface of the plastic resulting from the hydrophilic nature of the plastics or the high air content and porosity of the plastic concrete. The use of recycled plastic fibers with a high ultimate tensile strength and smaller fiber content results in a more significant improvement in compressive strength than fibers with low compressive strength. Also, straight fibers increased compressive strength more than those with embossed geometry (Fraternali et al., 2014). Additionally, the compressive strength of plastic concrete was increased with the injection of plasticiser (Rai et al., 2012).

It can be seen that the compressive strength of plastic concrete is likely to be increased substantially without compromising its performance if plastic particles are further processed or treated to improve the bonding of the composites in a superplasticised environment. The pulverization of the polyethylene into a powder is presumed to reduce their particle sizes, hence expected to increase the compressive strength. The limitations of most previous research attempts on the use of plastics in concrete were the fact that plastic used presented wider surface areas (which likely inhibited hydration of cement) or was not treated (which may have affected the bonding to cementing materials).

3.   METHODS
3.1. Materials

The materials used in this research are: 'BUA' (42.5R grade) brand of Ordinary Portland Cement conforming to ASTM C 150 (2015). Pulverised High-Density Polyethylene was sourced from landfills in Jimeta, Yola North Local Government Area of Adamawa State, Nigeria. The High-Density Polyethylene (HDPE) were first sorted, cleaned, washed, and mechanically pulverised into smaller particles passing a 2mm British Standard (BS) sieve and chemically treated with 20% hydrogen peroxide to make the particles hydrophilic. Sieve analysis was then performed on the pulverised High-Density Polyethylene after taking the samples to approximately Saturated Surface Dry (SSD) condition as shown in Figure 1.

Figure 1 Pulverised and Sieved High-Density Polyethylene

Hydroplast - 500 conforming to ASTM C 494 (2015) was procured at Armosil West Africa Garki, Abuja, and used as a superplasticiser. Good quality Zone I river sand passing through 4.75mm BS sieve sourced from Jere town in Kagarko Local Government Area of Kaduna State was used.

Table 1 Properties of Materials Used

Properties	Cement	HDPE	Fine Aggregate	Coarse Aggregate	Hydroplast-500
Specific Gravity	3.15	1.03	2.66	2.62	1.175
Standard Consistency	30%	-	-	-	-
Initial Setting Time (min)	60	-	-	-	-
Final Setting Time (min)	320	-	-	-	-
Bulk Density(Kg/m^3)	1440	-	-	-	-
Compressive Strength at 3 Days (N/mm^2)	11.3	-	-	-	-
Compressive Strength at 7 Days(N/mm^2)	25	-	-	-	-
Compressive Strength at 28 Days(N/mm^2)	46	-	-	-	-
Moisture Content (%)	-	0.55	0.13	0.2	-
Water Absorption (%)	-	0.067	0.38	0.29	-
Appearance	Grey	Ash-grey	-	-	Dark brown

The suitability of the sand for the intended use was ascertained in the laboratory in accordance with the provisions of BS EN 12620 (2013). 20mm nominal sizes natural machined crushed rock sourced at Dutse Alhaji, Abuja and potable water obtained from Nigerian Building and Road Research institute laboratory, supplied by the Federal Capital Territory Water Board was used. This water was used throughout this research work both for mixing as well as curing of

the concrete and in accordance with the provisions of ASTM C1602/C1602M (2012). The properties of the materials are presented in Table 1.

3.2. Methods

The high-density polyethylene was collected, sorted, cleaned, washed, and pulverised into smaller particles using a locally fabricated pulverizing machine. The High-Density Polyethylene powder was then subjected to pretreatment by immersing it in a 20% solution of hydrogen peroxide for 20 minutes and then sun-dried to saturated surface dry condition. Figure 2(a) and 2(b) shows the Scanning Electron Microscopy (SEM) images of the treated and untreated Pulverised HDPE. The concrete specimens were prepared at the Materials and Concrete Laboratory, Nigerian Building and Road Research Institute (NIBRRI) headquarters Abuja, Nigeria using (150 x 150 x150) mm steel moulds. The cubes were prepared in accordance with the provisions of BS EN 12390-3 (2002). Concrete mixes were prepared using the BRE method of mix design. Table 2 shows the number of materials required per cubic meter of concrete as computed by the mix design. The investigation was carried out on Grade 25 and Grade 50 concretes representing medium-strength concretes (Grade 25) and high strengths (Grade 50) concretes respectively.

The samples were prepared with the pulverised and treated HDPE of fine consistency, precisely those passing through 2.00mm BS sieve, and added in percentages of (0, 0.25, 0.5, 0.75, and 1) by weight of cement. Dosages of *hydroplast-500* in order of 1000litres/ 50kg by weight of cement was used throughout the study as recommended by the manufacturers to enhance the workability of the matrix.
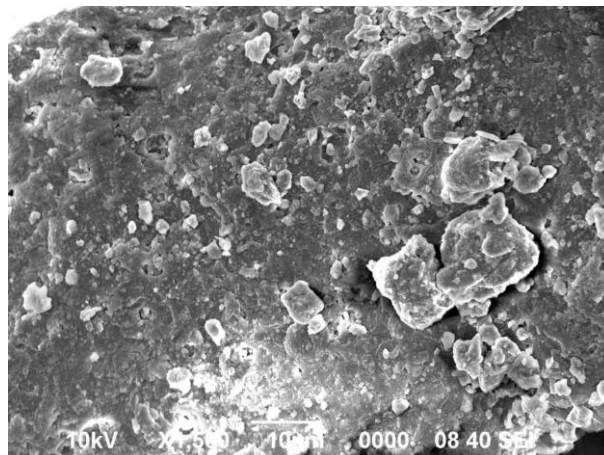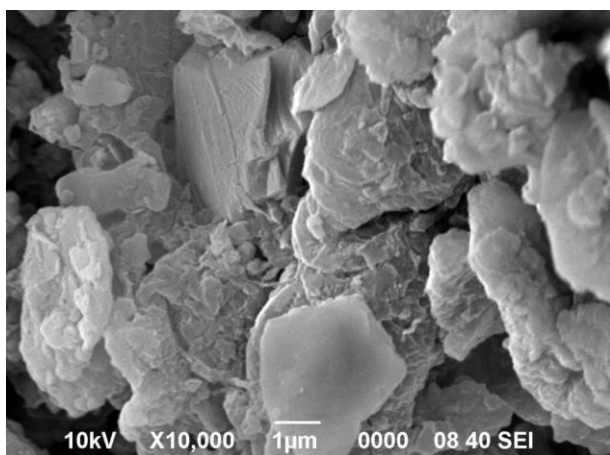
Figure 2(a) SEM image of Untreated Pulverised HDPE (X10, 000 Magnification)

Figure 2(b) SEM Image of Treated Pulverised HDPE (X1, 500 Magnification)

A constant water/cement ratio of 0.4 and 0.36 for requisite workability was adopted for Grades 25 and Grades 50 concretes respectively after trial mixes.

The fresh concrete was cast into the appropriate moulds (Figure 3) and vibrated for at least 25 seconds in accordance with ASTM C 192/ C192M (2016) using an electrically operated small size poker vibrator. After 24 hours of casting, the concrete beams were demoulded, weighed, and completely cured in water tanks. The compressive strength tests were carried out on the 150 x 150 x150 mm hardened concrete cubes after curing for 7, 28, and 90 days and in accordance with BS EN 12390-3 (2002) using a universal testing machine as shown in Figure 4.

Table 2 Quantity of Ingredients Required (kg) Per Cubic Metre of Concrete

Ingredient (Kg)	Concrete Grades	
	C25	C50
Cement	360	430
Fine Aggregate	630	570
Coarse Aggregate	1330	1330
Water	145	155
Hydroplast-500	7.2	8.6
Pulverized HDPE		
0.0%	*0*	*0*
0.25%	*0.90*	*1.08*
0.50%	*1.80*	*2.15*
0.75%	*2.70*	*3.25*
1.0%	*3.60*	*4.30*

Figure 3 Concrete Cubes Cast with (150 X 150) mm Steel Moulds

The average failure loads were used in obtaining the compressive strength, using the relationship in equation (2).

$$f_{cu} = \frac{P_{max}}{A}$$ …………………………………………………… (2)

Where:

	f_{cu}	=	Compressive Strength (N/mm^2)
	P_{max}	=	Magnitude of the Load at Failure (N)
	A	=	Cross-sectional Area of the Cube Specimen (mm^2)

Figure 4 Determination of Compressive Strength of Cubes Using Universal Testing Machine

4. RESULTS AND DISCUSSION

Figures 5 (a) and 5(b) show the relationship between compressive strength development and hydration periods of 7, 28, and 90 days for grades M25 and M50 concrete respectively. A critical analysis further revealed that the compressive strength of all concrete specimens increased with curing age compared on the basis of 90 days indicating that no noticeable degradation of the concrete occurred within the 90 days test. Compressive strength however decreased with the inclusion of pulverised HDPE with the least reduction of 19.09% ($29.67N/mm^2$) for Grade M25 while 16.04% ($45.32N/mm^2$) was recorded as the least reduction for Grade M50 concretes in all cases at 0.5% HDPE by weight of cement. This implies that 0.5 % HDPE content is the optimum content beyond which restrained hydration takes negative effects on the concrete. The reduction in compressive strength could be attributed to the restrained cement hydration reaction near the surface of the HDPE resulting from their hydrophilic nature.

The compressive strength of the control mixes was observed to be higher than that of all mixes containing pulverised HDPE. However, a minimum strength of $14.35N/mm^2$ and $25.05N/mm^2$ was obtained for Grade M25 concretes at 7 and 28 days of curing while a minimum of $33N/mm^2$ and $50N/mm^2$ was obtained for Grade M50 concretes at 7 and 28 days of curing respectively. These values correspond to the minimum expected designed strength of 65% at 7days of curing and 99% strength at 28 days of curing in water suggesting that the designed strength was satisfactorily met in all cases. This finding is considered as an improvement over the previous findings (Atul & Polytechnic, 2012; Gu & Ozbakkaloglu, 2016; Naik et al., 1996), who observed the same trend of strength reduction of the modified concrete with plastic materials. The improved performance in this study could be probably attributed to the reduction in the particle sizes of the HDPE via pulverisation as well as increased coverage of the polymer surface with R–OH and R– COOH sites produced by the oxidizing hydrogen peroxide during treatment of the HDPE. The treatment is believed to have made the particles hydrophilic, hence allowing them to adhere better to cement.
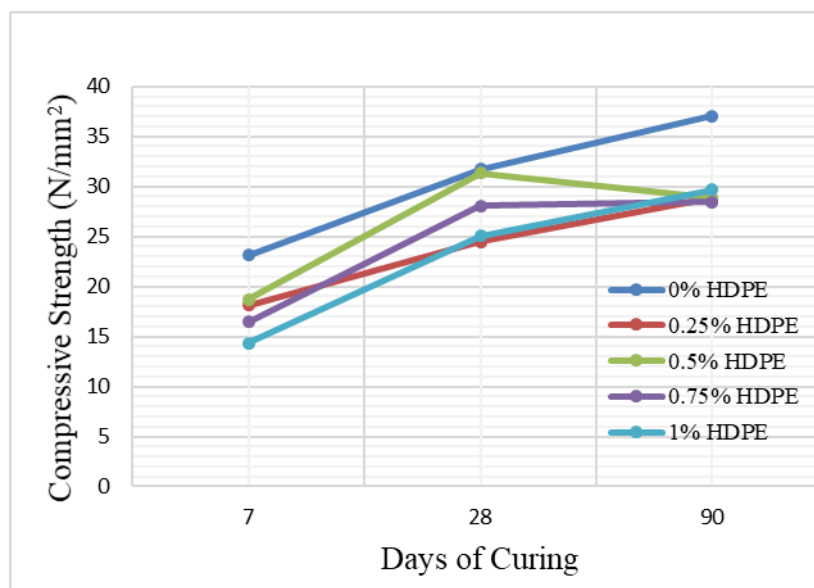
Figure 5(a) Compressive Strength with Curing Period for M 25 Concrete
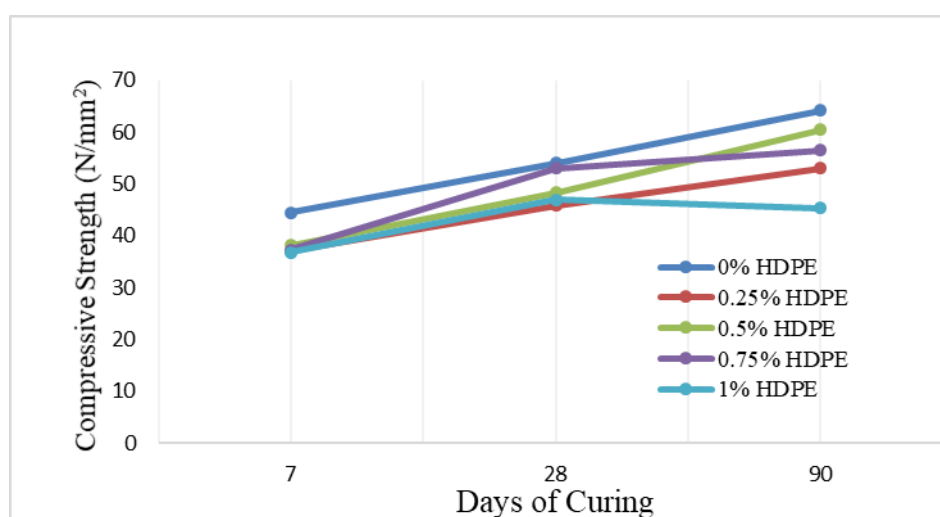
Figure 5(b) Compressive Strength with Curing Period for M50 Concrete

5. CONCLUSION

The following conclusions were drawn from the study of compressive strength characteristics of concrete modified with treated high-density polyethylene. The rough and reduced particle size with increased surface areas of the treated Pulverized High-Density Polyethylene as revealed by SEM substantially improved the bonding of plastic to cementitious materials as compared to the untreated samples.

Compressive strengths of all concrete specimens increased with curing age compared on the basis of 90 days tested but decreased with the inclusion of Pulversised High-Density Polyethylene with the least reduction of 19.09% (29.67 N/mm^2) for Grade M25 while 16.04% (45.32 N/mm^2) for Grade M50 concrete.

The study has shown the benefits of pulverisation and chemical treatment of HDPE on improving compressive strength properties of concrete, thus contributing to the body of knowledge on the use of waste plastic concrete. The study empirically revealed that the

incorporation of 0.5% of HDPE by weight of cement gives the optimum strength improvement for both Grade M25 and M50 concretes. The study has thus provided a guild to practitioners on the use of High-Density Polyethylene in concrete for construction purposes. Based on the findings of this study, it was recommended that 0.5% by weight of cement of treated pulverised HDPE could be used as an admixture in normal and high strengths concretes without compromising their compressive strengths.

This study limited the treatment of High-Density Polyethylene with only hydrogen peroxide. Therefore, the research suggested future studies to look at the effects of using other oxidizing chemicals for the treatment of High-Density Polyethylene. Similarly, the effects of treatment on HDPE should also be investigated.

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FEASIBILITY OF USING INFORMATION IN REAL ESTATE REGULATORY AUTHORITY DATABASE AS URBAN LAND DATA REPOSITORY

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ABSTRACT

The problem with the Indian real estate industry was of the lack of information and data, as well as a coherent and credible location for accessing the data. Another issue that plagued the sector until recently was that the market was unregulated, in which malpractices were rife. The Real Estate Regulation Act 2016 enacted by the government was a gamechanger in the real estate sector to address these issues. With the regulator coming into play, the consumers could access much information collated and make an informed decision. However, there are still several issues persists, such the credible and quick data access, complex coordination of records and approvals among multiple government departments and statutory bodies, and data not updated promptly. Therefore, this study aims to check the feasibility of an Urban Land Data Repository, drawn from the Real Estate Regulation Act 2016, by taking into account Indian four states of Uttar Pradesh, Madhya Pradesh, Haryana, and Maharashtra to identify potential data points for the proposed repository. The paper details the data points and the rationale for taking them, closing with an analysis of the current data availability for the proposed repository through this policy analysis paper.

Keywords: Real Estate Regulation Act; Standardization; Urban Land Use Data

1. INTRODUCTION

Indian real estate industry and its customer market has been gradually transformed over time. There are for major periods of transition of the real estate sector indicated (Joshi et al., 2019), which include initial period until 2008, period between 2008 and 2016, period between 2016 to 2020, and period post 2020 (see Figure 1). Beyond 2020 towards the future, the sector is expected to be more transparent, regulated, and consolidated. However, there are still some major barriers faced by the sector to obtain that goal, one of which is digitization of land records (Kumar, 2018). Therefore, it is necessary to digitize land records for a more effective land management as it is an essential in alleviating conflict management, supporting local governance processes, increasing property values, and reducing lender risk (Roth & McCarthy, 2014; Domeher & Abdulai, 2012).

The settlement in Indirapuram, Ghaziabad, developed with approximately 10-12 apartments in each building, showed that land records in India might observe a slight issue.

Even though Ghaziabad Nagar Nigam, also known as Ghaziabad Municipal Corporation, has registered the properties and provided a title deed to the owners against which the property tax is collected, the Ghaziabad Development Authority has still not updated the registration, so that the water tax and the sewer tax is paid on the property as a whole.

Till 2008	2008 to 2016	2016 to 2020	Post 2020
• Unorganised Industry • Family Driven Business • Role of Local Authorities confined to Approvals • Lack of Oversight in the Industry • Driven by Supply Side • Products Unsuitable for the market	• Shift to Corporate Houses • Entry of Global Investors • Unregulated & Fragmented Market • Supply-Driven Market • Introduction of Aspirational Products	• Introduction of RERA,2016 • Reforms such as IBC, GST, Benami Transactions Act introduced • Reforms aimed to support demand side of business • Protection of Customers & Investors	• Introduction of compliant developers • Consolidation of Existing Developers • Phasing out of Shadow developers • Organisation of the Sector

Figure 1 Tracing the History of Real Estate in India Data (Source: Joshi et al., 2019)

This fact represents a big issue in the coordination system among responsible agencies in India. Many documents are created, issued, submitted, and stored in one department when a property transaction occurs, however the other department is unaware of these documents. It creates a possible point for disputes to occur. Previous studies conducted by Gopalan (2014), Morris (2010), and World Bank (2011), also showed that data duplicity has become a critical issue in land management in India. However, with the introduction of the Real Estate Regulation Act in 2016, there is an opportunity to take a step forward to create an Urban Land Data Repository that can be used for various purposes, the details of which can be seen in Figure 2.

CORRELATE PROPERTY INFORMATION ACROSS DEPARTMENTS	SERVE AS DATABASE FOR INDUSTRY ANALYSIS
UNDERSTAND TRENDS IN THE MARKET	**STANDARDIZATION OF REAL ESTATE DATA**

HELP IN PROFESSIONAL REAL ESTATE MANAGEMENT

Figure 2 The Use of the Proposed Urban Land Data Repository (Source: Authors, 2021)

The study, in the form of a policy analysis, undertaken by the authors aims understand the need for an Urban Land Data Repository in the Real Estate market. It also aims to assess the feasibility of using the different data sets available with the government and other stakeholders to create a repository. The researchers also aim to identify the data required and the stakeholders in charge of the said data to assess the process of integration, and finally analyse

the concept of an Urban Land Data Repository to identify the data points required to devise an effective system as well as from the perspective of data entry.

2. INDIAN REAL ESTATE REGULATION ACT

Data access and analysis is one of the biggest problems in India. Much data is generated through different programs, but many are stored in silos where the impact of the change in one is not reflected in the other. The biggest hurdle that came across while researching for the project online was the staggered way the information is stored.

World Bank (2011) stated that the multiplicity of urban bodies is an issue in urban management. It was also acknowledged in a study by Morris (2010) showing that the sector has issues with the information provided to buyers. The core of which is the information management and the information exchange. Gopalan (2014) also stated that poor land record management is ailing the Indian sector.

There were not much available data could be found while using Real Estate Regulation Authority (RERA) database as a property data management portal. This fact highlights the necessity of the existence of such a database in the country. Furthermore, while RERA Act was created and enacted by the Union Government, the states were empowered to create regulations concerning the implementation. Therefore, each of the states has asked for a great degree of information and how it has been utilized.

This study conducted an analysis began with analyzing and comparing the information required for the registration of a project as per the Central RERA Act (Indian Ministry of Law and Justice, 2016) and the regulations enacted by the States of Uttar Pradesh (Government of Uttar Pradesh, 2017), Maharashtra (Housing Department, Government of Maharashtra, 2017), Madhya Pradesh (Government of Madhya Pradesh, 2017), and Haryana (Haryana Government, 2017). For example, PAN Card, one of the most critical documents for financial transactions, is missing as a mandatory document from the Central RERA Act but has been included by Uttar Pradesh, Madhya Pradesh, and Maharashtra in their regulations. Madhya Pradesh has also gone ahead and included AADHAR Cards (biometric document storing personal details in a government database) of the promoters that need to be submitted to register the project.

While this is one of the differences, it can also be seen that the states have drafted the regulations in many different forms, and the documents vary from state to state, which, while good from a regulation perspective, can be a logistical nightmare for a developer working across states, or a researcher looking for information to analyze.

Coming to the second point, the representation of data across these states varies as well. At the same time, Maharashtra uses a GIS-based web application to represent the projects on a map which makes locating the project more manageable. While Madhya Pradesh Real Estate Regulation Authority (MP RERA) has created its dashboard using Microsoft Power BI that is easy to use but not user-friendly, Uttar Pradesh has no dashboard. Therefore, the details of the project should be entered into the page to find a project. For the portal made by Haryana RERA, identifying the project ID to enter into the search is difficult as they have used a complicated way of allotting the numbers.

Going through the above information and the different documents perused during the study, one thing that jumps out is the lack of standardization of information, and each state or each district has its own set of documents that are a significant issue while going online.

Furthermore, collating information spread across departments is a massive task in itself since there are almost 150 types of information fed into the RERA database to register a project. This

information is usually verified so that it proves to be an influential information bank if used correctly. Besides, since the documentation is updated for new projects, slowly, the issue of outdated land records, ownership disputes, etc., can also be resolved.

While going through the RERA 2016 with the rules enacted by Maharashtra, Madhya Pradesh, Uttar Pradesh, and Haryana, a comparison of other aspects of the Act with the rules enacted by the states was also done. The comparison was made on the Insurance of the Real Estate project, Transfer of Title, Compensation by the Promoter, Rights, and Duties of the Allottees, Settlement of Disputes, and Offences and Penalties.

The concept of the Insurance of Real Estate Project is present in the RERA 2016 (Indian Ministry of Law and Justice, 2016). However, no mention of the same is present in the rules enacted by Uttar Pradesh, Madhya Pradesh, and Haryana, but the rules enacted by Maharashtra (Housing Department, Government of Maharashtra, 2017) mention it to be the same as per the Central Act.

The second aspect, RERA 2016, details aspects regarding the Transfer of Title, including what, how, and when the information transferred from the developer to the allottee or the association, as the case may be. While the rules specified by Uttar Pradesh, Madhya Pradesh, and Haryana are silent on this, Maharashtra mentions it to be the same as the Central Act but differs in the period in which the transfer is to happen. While the Central Act specifies the transfer within three months from the issue of occupancy certificate issue, the MahaRERA rules (Housing Department, Government of Maharashtra, 2017) specify it to be three months from the date on which fifty-one percent. Of the total number of allottees in such a building or a wing have booked their apartment.

The third aspect under contention is Compensation by Promoter. If the promoter/developer is unable to complete or hand over unit possession as per the terms of the contract, the Act specifies the compensation that an allottee is entitled to if they either wish to withdraw or not. Comparing it with the rules by the respective states, it is the same as per the Central Act.

RERA was enacted to empower customers; therefore, the part lists out the Rights and Duties of Allottees is quite critical. The Central Act details the various rights and duties of the allottees of a Real Estate project, while the State rules in the investigated four states do not specifically address the concept. However, since all of them reference the Act in the description, therefore, the one in the Central Act should apply to all state rules.

The last point compared during the review concept is one of Offenses and Penalties. Under Chapter VIII, Sections 59 through 72, the Act specifies the offenses under the Act, its penalties, and the compounding of offenses under various heads. Regarding the state rules, the ones enacted by Uttar Pradesh, Madhya Pradesh, and Haryana specify how the offenses are compounded; the rules enacted by Maharashtra are silent on this.

3. METHODS

This study is a policy analysis work that aims to understand if the established data in the field of Real Estate through various Acts and Rules enacted by the government can be used to populate an Urban Land Data Repository. The study started with identifying the data points from data entry, issue, and user point of view in RERA bodies, Urban Local Bodies, and other bodies, where applicable for land records of Uttar Pradesh, Madhya Pradesh, Maharashtra, and Haryana. It was then followed by checking the status of digitization of the records and their access in the public domain, followed by the comparison of the same and identification of best practices and gaps, and identification of data points which can be used in the proposed Urban

Land Database along with the source and type of information. However, as the study is primarily a policy analysis, it does not have any qualitative or quantitative analysis tools being used.

The first step in the study was to study the RERA, 2016 as enacted by the Union Government and list out all the data that can be extracted using the provided information by the promoter registering the project as well as the real estate agent registering themselves as per the provisions of the Act. It was further followed by reading the act clause by clause, focusing on the ones about the registration of projects under Chapter 2, Clause 4 of the Act, and identifying the information mandated for the registration of the project by the promoter. Along with this, each document was checked to identify any indirect information using the provided information. For example, the registration number of the architect with the CoA, which is not stated in the Act but is a part of all approved drawings. A similar activity was done with the rules enacted by the respective state governments of Maharashtra, Uttar Pradesh, Madhya Pradesh, and Haryana to identify any additional information mandated by the respective states, which could be a best practice for the proposed repository. Once the identification of the data points was complete, the next step was to take up two examples of each of the registered ongoing projects to see how the information is accessible in the public domain and whether all the listed-out information as per the Act is available on the respective websites of the authorities. Finally, once this database was populated, 35 data points were identified as possible options for the proposed database, the reasons, sources of such information, and its utility.

Based on the background study during the literature review and the gap analysis, the aims are to check the feasibility of an Urban Land Record Database that can collate the various information relating to Real Estate across departments and provide single point access to the same for different stakeholders. The data collected from the RERA 2016, and the respective state regulations of Uttar Pradesh, Maharashtra, Madhya Pradesh, and Haryana were classified into different broad areas to ease the process of data mining and selection.

The data points identified were further classified as Direct Input, which is the information that is entered directly into the RERA database and no other document needs to be referred to gather this, and Indirect Input, which is the information that can be extracted from the information that is directly entered in the RERA Database and is pertinent to the case at hand.

In the tables appended with each of the Broad Areas, the cell highlighted in green means the respective information is available in the respective Act/Rule.

Broad Area 1: Details of Promoters

Promoters are the most critical stakeholders during the project duration; therefore, a project is usually known by its name.

Under Section 4 of the RERA, 2016, a promoter needs to be registered with the respective Real Estate Regulatory Authority of the respective state, and then it is authorized to register a project.

During the study, it was found that while the Central Act mandates only seven information points as mandatory for registration of a promoter, the states have taken a step ahead and made it even more stringent by introducing additional information points. The data field as per the respective RERA Regulation. The data field as per the respective RERA Regulation was summarized in Table 1.

Table 1 Data for Details of Promoters (Source: Respective RERA Websites)

Data Field	RERA Act	Maha RERA	UP RERA	MP RERA	Haryana RERA
Name	✓	✓	✓	✓	✓
Registered Address	✓	✓	✓	✓	✓
Type of Enterprise	✓	✓	✓	✓	✓
Particulars of Registration	✓	✓	✓	✓	✓
Photographs of Promoters	✓	✓	✓	✓	✓
Website	✓	✓	✓	✓	✓
Phone Number	✓	✓	✓	✓	✓
PAN		✓	✓	✓	✓
The audited balance sheet of the promoter for the preceding financial year			✓	✓	
Income tax returns of the promoter for three preceding financial years			✓	✓	
Educational Qualification of Promoter			✓	✓	
Work experience			✓	✓	✓
Number of years of experience of the promoter or parent entity in real estate construction in the state			✓	✓	✓
Number of years of experience of the promoter or parent entity in real estate construction in other states or union territories			✓	✓	✓
Number of completed projects and area constructed till date;			✓	✓	
Registration Date			✓		
CIN			✓		
Residential Address of Promoters				✓	✓
AADHAR Number				✓	
Audited Profit & Loss Account for last three years				✓	
Auditor's Report for last three years				✓	
Annual Report for last three years					✓

The emphasis put on the details of developers, especially on the books, registration, CIN, etc., shows that it is one of the crucial datasets for the study.

Broad Area 2: History of Projects Launched

With the country facing a trust deficit in the real estate market due to various issues like the unsold inventory of 3.7 Lakh Crore Rupees (Economic Times, 2020) and delay in delivery of older projects, which were the reasons for the introduction of the Regulator, history of project of the developer under consideration become a critical point for a customer to make an informed decision. The same is critical for a financial institution as it can understand the history of its performance and act accordingly.

While the Act itself outlines only five sets of information to be provided, the regulations by Maharashtra RERA in this respect are pretty meticulous and help an information seeker to a great deal. Madhya Pradesh, Uttar Pradesh, and Haryana have retained the points from the Central Act, with some minor additions.

Table 2 Data for History of Projects launched (Source: Respective RERA Websites)

Data Field	RERA Act	Maha RERA	UP RERA	MP RERA	Haryana RERA
Status (Completed/Pending)	✓	✓	✓	✓	✓
Delay in Completion	✓	✓	✓	✓	✓
Details of Cases Pending	✓	✓	✓	✓	✓
Details of Type of Land	✓	✓	✓	✓	✓
Payments Pending	✓	✓	✓	✓	✓
Name of Previous Projects		✓	✓	✓	✓
Type of Project		✓			
Land Area		✓		✓	✓
Project Address		✓		✓	
Number of Buildings		✓			
Number of Apartments		✓			
Proposed Date of Completion		✓			
Actual Date of Completion		✓			
RERA Registration Number					

Broad Area 3: Authenticated Documents

To substantiate claims made by a developer, the Act mandates a set of authenticated documents that need to be provided during registration. As authenticated and certified, they are the source of some potentially important information that can be critical to the proposed database.

Table 3 Data for Authenticated Documents (Source: Respective RERA Websites)

Data Field	RERA Act	Maha RERA	UP RERA	MP RERA	Haryana RERA
Approval Certificate (Project/Phase)-Layout	✓	✓	✓	✓	✓
Approval Certificate (Project/Phase)-Building Plan	✓	✓	✓	✓	✓
Layout Plan	✓	✓	✓	✓	✓
Commencement Certificate	✓	✓	✓	✓	✓
Application Number for Commencement Certificate	✓	✓	✓	✓	✓
Application Date for Commencement Certificate	✓	✓	✓	✓	✓
Plot Number	✓	✓	✓	✓	✓
Legal Title to Land	✓	✓	✓	✓	✓
Application Number to the Municipal Authority		✓	✓		
Layout Approval Registration Number		✓	✓		
Building Plan Registration Number		✓	✓		
Authentication of Land title by Practicing Advocate/ Land Search Title Report (UP, Har)		✓	✓	✓	✓
Authenticated copy of occupancy certificate/completion certificate			✓		✓

The authenticated documents are essentially derived from the other government and regulatory bodies and hence, serve as a bridge between the proposed database and the data owners. Each of these documents usually has an identification number which can prove to be a backbone of the data-sharing system.

Broad Area 4: Project Information

Coming to the details of the project in focus, these sets of information are the most extensive in the Act as they talk about the present and impact the stakeholders the most. These are the projects that can be controlled and checked in real-time.

Project information also forms a critical part of the proposed data repository as it will ultimately add to the property database and help create a real-time property database in the urban areas and avoid future litigations.

While the Act provides 14 data points, the states have taken reasonable steps to detail the clause to incorporate as many details of the project as possible to be fully informed, and a proper decision can be taken.

Table 4 Data for Project Information (Source: Respective RERA Websites)

Data Field	RERA Act	Maha RERA	UP RERA	MP RERA	Haryana RERA
Date of Issue of Commencement Certificate	■	■	■	■	■
Validity of Commencement Certificate	■	■	■	■	■
Comments by Authority on CC	■	■	■	■	■
Sanctioned Plan	■	■	■	■	■
Name of Architect	■	■	■	■	■
Serial Number of Approval of Plan	■	■	■	■	■
Approver of Plan from the Authority	■	■	■	■	■
Specifications of the Project	■	■	■	■	■
Plan of Development Works	■	■	■	■	■
Geographical Location of the Project (Longitude & Latitude)	■	■	■	■	■
Number of Apartments/Plots	■	■	■	■	■
Type of Apartments	■	■	■	■	■
Number of Garages	■	■	■	■	■
Area of garage	■	■	■	■	■
Project Name		■	■	■	■
Project Status		■	■		
Proposed Date of Completion		■	■		
Litigations Related to Project		■			
Project Type		■	■		
Plot Number		■	■		
State		■	■		
Division		■			
District		■	■		
Taluka/Village/Tehsil		■	■		
Pin Code		■	■		
Total Buildings Count		■			
Sanctioned Buildings Count		■			

Data Field	RERA Act	Maha RERA	UP RERA	MP RERA	Haryana RERA
Area (Square meter)		▓	▓		
Aggregate Area of Open Space		▓			
Built-Up Area As per Proposed FSI		▓			
Built-Up Area As per Approved FSI		▓			
Total FSI		▓			
Amenities Provided		▓			▓
Defect Liability Period		▓			
Is the Project a Green Building		▓			
Name of Facility Management Company		▓			
Carpet Area of Flat/Plot Size		▓	▓		▓
Exclusive Areas for the Flat		▓	▓		▓
Number of Floors		▓			
Aggregate Area of Recreation Space		▓			
Nature of the organization of allottees to be constituted		▓			
Number of open Parking Areas			▓	▓	▓
Consent to Establish and Operate			▓		▓
Environmental Clearance			▓		▓
Fire NOC			▓		▓
Permission from Water and Sewerage Department			▓		▓
Height clearance from Airport Authority of India (if applicable)			▓		▓
Floor plans for each tower and block, including clubhouse, amenities, and common areas			▓		▓
Registration Fee			▓		
Project Duration			▓		
Sanctioning Competent Authority			▓		
Project Cost			▓		
Advertisement/Prospectus				▓	▓
Name of Landowner					▓
Contact Details of Site Office					▓

Broad Area 5: Details of Consultants

While creating a database of real estate projects, one parameter that draws importance is the details of consultants engaged in a project. Each project has many people engaged in various capacities and strives to help the project develop. While the RERA Act mandates the provision of the name and address of each of the consultants, that itself is not enough for a precise search.

It was a typical case where each state presented a different aspect of this to the authors. While the architect's details can be extracted from the approved drawings along with their registration number with the CoA, the CA registration number can be extracted from the periodical updates on progress, etc.

This information is critical in creating a searchable database as it would help stakeholders pinpoint which consultants are handling how many projects and identify any issues that might crop up.

Table 5 Data for Details of Consultants (Source: Respective RERA Websites)

Data Field	RERA Act	Maha RERA	UP RERA	MP RERA	Haryana RERA
Name of Consultants	■	■	■	■	■
Address	■	■	■	■	■
CoA Registration Number		■			
Chartered Accountant Registration Number		■			
Name of Firm			■		
Year of Establishment			■		■
Name of Key Projects Completed			■		■
Profile of Key Projects Completed			■		■

Broad Area 6

It is a data point in which the RERA is of little help. The Central Act mandates that the proforma for the allotment letter, agreement for sale, and the conveyance deed proposed to be signed with the allottees are to be uploaded to the respective project portal on the authority website.

Based on the limited information on this aspect and with the proforma unavailable for the examples undertaken for Madhya Pradesh and Haryana, the data points from Uttar Pradesh and Maharashtra Examples have been taken.

While these could get embroiled in data privacy issues, to have an effective Property Management Database, it is critical that the customer information also gets captured in the system to ensure proper tracking of transactions and ownership.

Table 6 Data for Details of Customers (Source: Respective RERA Websites)

Data Field	RERA Act	Maha RERA	UP RERA	MP RERA	Haryana RERA
Date of Allotment		■			
Flat Number		■			
The floor on which Flat Allotted		■			
Sale Consideration Amount		■			
Customer Name		■			
Customer Address-Correspondence		■			
Date of Birth/Date of Incorporation		■	■		
PAN		■	■		
AADHAR Number		■			
Nationality		■			
Passport Number		■	■		
Customer Address-Permanent		■	■		
Contact Number		■	■		
Email ID		■	■		
Mode of Booking		■	■		
Name of Financing Bank		■	■		

Broad Area 7: Financial Information

Going by the central RERA Act, the bank name and the IFSC of the bank are required to register a project, but the states have taken the initiative and added some more checks into the system.

While Maharashtra adds on three direct data points and another eight indirect data points emerge from various documents uploaded onto the database, Uttar Pradesh includes a consent letter from the bank providing the construction finance and the banks with which the project has collaborated for home loans. Madhya Pradesh and Haryana follow the central Act in this respect, but Haryana adds on the project's bank account number.

This financial information is essential to identify projects being financed by a particular branch of a particular bank as in light of events that have transpired in the last few years, even one project is enough to unravel a financial mess.

Table 7 Data for Financial Information (Source: Respective RERA Websites)

Data Field	RERA Act	Maha RERA	UP RERA	MP RERA	Haryana RERA
Bank Name	■	■	■	■	■
IFS Code	■	■	■	■	■
Payment Schedule/Plan		■	■		
Land Cost		■			
Cost of Construction		■			
Estimated Cost of Real Estate Project		■			
The premium payable to obtain development or redevelopment rights		■			
Amount paid for acquisition of TDR.		■			
The premium for grant of FSI, including additional FSI		■			
Stamp Duty		■			
Transfer Charges		■			
Registration Fee		■			
Interest Rate		■			
Consent Letter from banks for construction finance			■		
Consent Letter from banks for Home Loans Tie-Ups			■		■
Name of Account Holder			■		
Bank Address			■		
Bank Account Number					■

Broad Area 8: Proforma of Documents

It is mandated by the Central RERA Act that the proforma of the Agreement for Sale and the Conveyance Deed be uploaded by the developer on the project page with all the relevant details to standardize and ensure fair practices by the developer, keeping in mind the rules notified by the respective authority.

This set of documents are vital as many indirect information parameters can be derived from this.

Apart from the mandatory documents, Maharashtra, Uttar Pradesh, and Haryana have also mandated the uploading of the Application form that would be used to collect customer information.

Despite being just standard formats in the RERA database, including these here is that they are a key to identifying the customer-related and project-related information.

While preparing the proposed ULDR, looking for information on the registered deeds would become more accessible, and thus the process of data mining becomes simpler.

Table 8 Data for Proforma of Documents (Source: Respective RERA Websites)

Data Field	RERA Act	Maha RERA	UP RERA	MP RERA	Haryana RERA
Allotment Letter & Agreement for Sale	✓	✓	✓	✓	✓
Conveyance Deed	✓	✓	✓	✓	✓
Application Form		✓	✓		✓

Broad Area 9: Legal Information

Every project, while registration, has to either provide a land title in the developers or the promoters name or a collaboration agreement which eliminates the possibility of disputes arising later concerning land ownership.

Another thing that comes out of the land title document is the transaction history that has happened on the land under scrutiny, and that it would help create a log of all the transactions that happened and the relevant paperwork.

It forms a concept of an Urban Land Data Record concept, as the history concerning land is available, but the similar related to the built environment is not.

Table 9 Data for Legal Information (Source: Respective RERA Websites)

Data Field	RERA Act	Maha RERA	UP RERA	MP RERA	Haryana RERA
The declaration that land is free of encumbrances	✓	✓	✓	✓	✓
Conflicts wrt land		✓	✓		
History of Transactions		✓	✓		
Details of Ongoing Litigation in the state for past five years					✓

Broad Area 10: Status Updates

It is an essential factor that brings out the efficacy of the Regulator. If one has the RERA Registration number of a project, they can view the project's current progress. It helps people analyze the ongoing projects as well as understand the path their investment is taking.

Table 10 Data for Status Updates (Source: Respective RERA Websites)

Data Field	RERA Act	Maha RERA	UP RERA	MP RERA	Haryana RERA
Status of construction of each building with photographs					
Status of construction of each floor with photographs;					
Status of construction of internal infrastructure and common areas with photographs					
Approval received					
Approvals applied and expected date of receipt.					
Approvals to be applied and date planned for application					
If there are any modifications, amendments, or revisions, it is issued by the competent authority concerning any license, permit, or approval for the project.					

4. Data Fields for Proposed Urban Land Data Repository

4.1 Introduction

Based on the background research and how much information related to the built environment gets accumulated, it would be helpful if the relevant information can be extracted and collated onto a single portal that can ease the issues plaguing the Indian Built Environment sector's lack of data.

The data points identified in the previous section are currently owned and controlled by multiple agencies, and more often than not, a search for information might just lead one from pillar to post. This compartmentalization of information also leads to irregular updating of information, leading to incorrect information, which might convert into legal disputes.

This study proposes the creation of an Urban Land Data Repository (ULDR) that derives information from the RERA Authorities that they get with the registration of the following:

- Promoter/Developer
- Project
- Real Estate Agent

As outlined in the previous section, multiple data points can be used to extract information. While RERA remains the primary source of information, some identifying parameters can be picked up from the details uploaded in the RERA database and used as a bridge between various departments, hence helping the proposed ULDR be one place data related to property.

A total of 35 data fields were identified, taking the data points from the previous chapter as the base. These data fields were segregated based on the type of source they relate to and then tabulated. The identified data sources are Consultant, Customer, Developer or Promoter, Project, and Real Estate Agent. The proposed ULDR fields can be seen in Figure 3.

Proposed Urban Land Records Database

Section 1a: Project Details		Section 1b: Customer Details	
RERA Registration Number		Date of Allotment of Unit to Customer/Date of Transaction	
Project Name		Aadhar Number of Customer	
Project Status		Financing Bank for Customer-Name	
Proposed Date of Completion		Property ID issued by Development Authority	
Litigations Related to Project			
Project Type		**Section 1C: Architect Details**	
Proforma for Agreement for Sale		Council of Architecture Regn Number of Architect	
Number of Units in the Project		Name of Architect	
Type of Units in the Project		**Section 2: Consultant Details**	
Carpet Area of Units		Name of Consultants	Address of Consultants
Financing Bank for Developer-Name			
Financing Bank for Developer-IFSC			
Layout Approval Number			
Commencement Certificate Number			
Plot Number			
Geographical Location of the Project (Longitude & Latitude)		**Section 3: Developer Details**	
Land Record Number		CIN	
Regn. Number of Legal Body for Legal Entity for Common Areas		DIN	
Land Cost (Lakhs)		Photographs of Promoters	
Cost of Construction (Lakhs)		Website of Developer	
Estimated Cost of Real Estate Project (Lakhs)		Name of Developer	
Section 4: Real Estate Agent Details			
RERA Number of Real Estate Agent		Name of Real Estate Agent	PAN of Real Estate Agent
Links for Verification			
RERA Number			
CoA Number		https://www.coa.gov.in/ver_arch.php?lang=1	
CIN		http://www.mca.gov.in/mcafoportal/viewCompanyMasterData.do	

Figure 3 Sample Design of the Proposed Repository (Source: Authors, 2020)

As discussed earlier, for this study, four states were taken as a sample to understand and analyze the variations in the notified rules by each state. Two random examples from each state were taken, and a proforma of the proposed ULDR was filled to verify the status and how information has been put in the database.

While customer information for none of them could be obtained due to constraints, the table (see Table 11) summarizes the extent of information available in the four states. The data was as of April 2020 when the study was conducted.

Table 11 Availability of Information for a proposed repository under current scenario (Source: Authors, 2020)

| RERA Body	Location	Project Details	Customer Details	Architect Details	Consultant Details	Developer Details	Real Estate Agent Details	Overall
HARERA	Gurugram	80.95%	0%	100%	0%	80%	0%	58.97%
HARERA	Panchkula	80.95%	0%	100%	25%	100%	0%	64.10%
MPRERA	Indore	76.19%	0%	100%	100%	60 %	0%	64.10%
MPRERA	Bhopal	76.19%	0%	100%	100%	60%	0%	58.97%
MAHARERA	Mumbai	80.95%	0%	100%	100%	100%	100%	89.47%
MAHARERA	Pune	80.95%	0%	100%	100%	100%	0%	71.79%
UPRERA	Lucknow	80.95%	0%	100%	100%	100%	100%	89.19%
UPRERA	Noida	80.95%	0%	100%	100%	100%	100%	88.89%
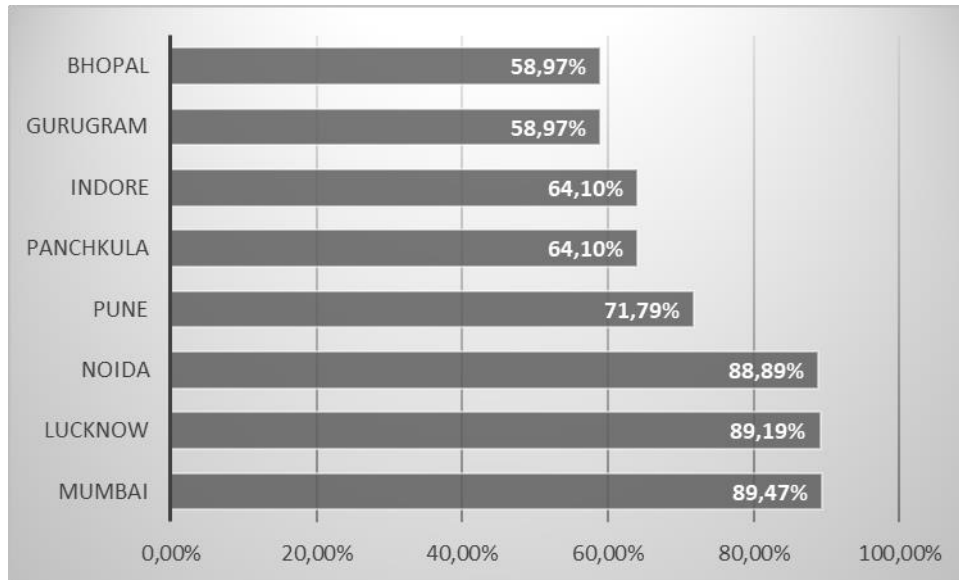
Figure 4 Ranking of Sample Projects as per availability of Information for ULDR-City wise
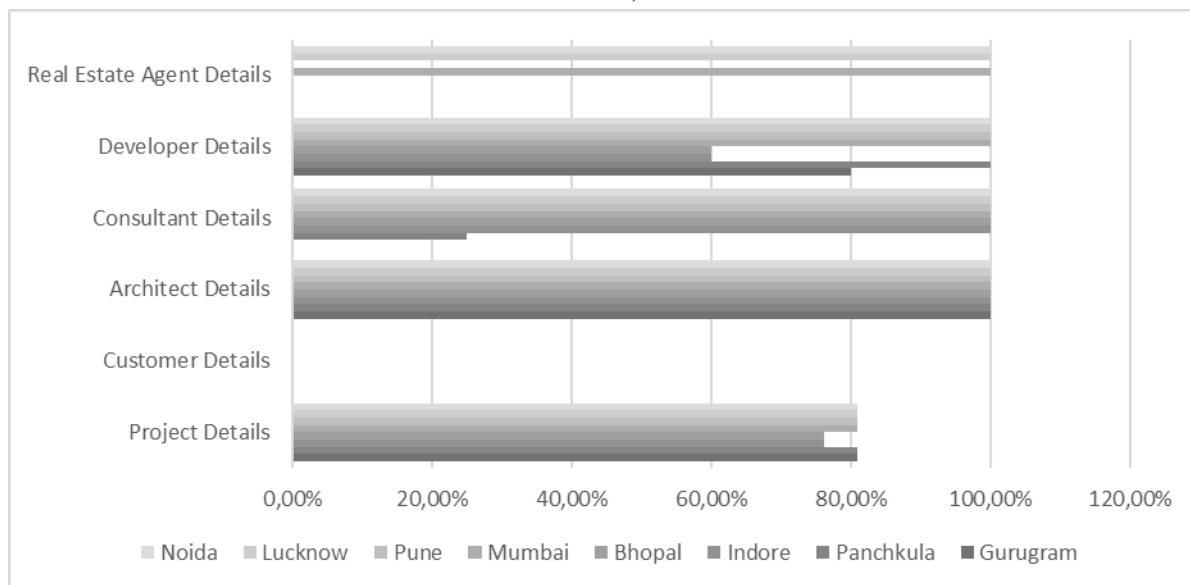(Source: Authors,

2020)

Figure 5 Ranking of Sample Projects as per availability of Information for ULDR-Section wise
(Source: Authors, 2020)

It can be seen from Figure 4 and Figure 5 that the details of the architects and the ones related to projects are readily available in the public domain, using the RERA website, MCA website, and the Council of Architects. Section-wise, all eight examples fared similarly on project details, with around 75 to 80 percent information readily available. For Details of Consultants, the HARERA projects were complex; otherwise, that was readily available in all the other six examples. Coming to the details of the developers, it was a mixed bag with Maharashtra and Uttar Pradesh having 100 percent of the information, but MP RERA took a backseat here. Coming to a surprise inference from this exercise, the details of the Real Estate Agents attached to a particular project were missing in Haryana and Madhya Pradesh examples. For the project in Pune, the information was missing, but for the one taken for Mumbai, the information was available. It goes on to show that while we have the rules in place, we need to move to a more

vital vigilance on the information that is being provided; otherwise, the purpose of the regulation in the sector gets defeated.

5. RESULTS AND DISCUSSION

The policy analysis aimed to analyze the existing framework under the RERA, 2016 and the rules enacted by the states to bring together an Urban Land Data Repository that would be an effective property information system for Urban Areas. As per the study, it is feasible to draw upon the existing rules and framework to build a possible Urban Land Data Repository to collate the information spread across various departments and agencies concerning the real estate market.

The analysis also shows that the proposed repository is a need of the hour as currently the data for Real Estate in India is quite fragmented, and the creation of such a repository would help the Industry and the Academia equally by providing verified data at a single location.

In conclusion, it can be said that an Urban Land Data Repository, based on the Real Estate Regulation Act and the various rules on it, is a feasible option for the Indian market.

There were some issues faced during the study that could hamper the creation of the Urban Land Data Repository; therefore, the following recommendations are made so that this can be streamlined:

1. Standard Format of the RERA Registration number for Projects, Developers, and Real Estate Agents.

2. Standardization of the documents required during registration of project, developers, and agents.

3. GIS onboarding of all land parcels in Urban as well as Rural areas so that an effective land database can be created.

4. Since the proposed ULDR also incorporates Customer information, it is recommended that access control be done using a registration token during the detailing so that access can be monitored.

5. The access to the proposed ULDR can be partially free and partially paid to maintain the sanctity of sensitive information.

The proposed ULDR should be notified by the Central Government and not be drawn up by individual states, leading to a mismatch in information.

The concept is basically a work in progress and open-ended. The scope is being explored that RERA can use as a property data management portal. Initially, it was not designed in this manner, but it could be a potential data management portal due to its access to such data. It is explorative research that is open-ended at this point, with a scope of further research that needs to be done in different aspects to justify the reorientation of RERA as a property data management portal.

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